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THE

MINERALOGICAL MAGAZINE

AND

Journal of

The Mineralogical Society.

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EDITED BY L. J. SPENCER, M.A.

ASSISTED BY A COMMITTEE OF COUNCIL.

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1917.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 7, 1916, *at* 5 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

The death of Dr. R. H. Scott, F.R.S., a Past-President and Trustee of the Society, was announced, and the Secretary was requested to send a letter of condolence to the relatives.

The following were selected as the dates of the meetings in 1917: Tuesdays, January 16, March 20, June 19, and November 6 (Anniversary Meeting).

The draft Annual Report of Council, submitted by the Secretary, was read and approved.

A vote of thanks was passed to Dr. G. F. Herbert Smith for sending notices of the meetings of the Society to 'Nature' and other periodicals.

The motion to be brought forward at the General Meeting that Trustees should be *ex officio* Members of Council was approved.

A Committee consisting of the Officers and Messrs. Ashcroft, Barker, and Evans was appointed to consider the future position of the Journal.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 7, 1916, *at* 5.30 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

Sixteen Members and three Visitors were present.

The President nominated Messrs. Holmes and Mennell to act as scrutineers of the voting-papers for the election of Officers and Council. The scrutineers reported that thirty voting-papers had been returned to the Secretary, and that the list as nominated by the Council was approved, namely:

President. W. Barlow, F.R.S.
Vice-Presidents. Prof. H. L. Bowman, M.A., D.Sc., F.G.S.
A. Hutchinson, M.A., Ph.D., F.G.S.
Treasurer. Sir William P. Beale, Bart., K.C., M.P., F.G.S., F.C.S.
General Secretary. G. T. Prior, M.A., D.Sc., F.R.S.
Foreign Secretary. Prof. W. W. Watts, LL.D., Sc.D., F.R.S.
Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

T. V. Barker, M.A., B.Sc., F.C.S.
G. Barrow, F.G.S.
H. Collingridge, B.Sc., F.G.S.
T. Crook, F.G.S.
Prof. C. G. Cullis, D.Sc., F.G.S.
J. W. Evans, LL.B., D.Sc., F.G.S.
F. H. Hatch, Ph.D., F.G.S.
J. Allen Howe, B.Sc., F.G.S.
F. P. Mennell, F.G.S.
G. F. Herbert Smith, M.A., D.Sc., F.G.S.
Capt. W. Campbell Smith, M.A., F.G.S.
H. H. Thomas, M.A., Sc.D., F.G.S.

The following Annual Report of Council was read:—

During the Session 1915–16 four meetings have been held (by kind permission) in the Apartments of the Geological Society, Burlington House, W., at which twenty-one papers were read. One number of the Journal has been issued, viz. No. 82 published in April 1916. This contains ten papers, including one on chabazite and associated minerals from Co. Antrim, the cost of the four plates of which was defrayed by Mr. Ashcroft.

The balance-sheet of the year ending December 31, 1915, shows that the financial position of the Society continues to be satisfactory. The assets (exclusive of the Library and stock of the Journal) amounted to £991 7*s.* 9*d.*, and the liabilities to £18 15*s.* 10*d.* The value of the Stock now invested in the second 4½ % War Loan in the names of the Trustees of the Society was on that date £774 18*s.* 8*d.*, corresponding to £14 12*s.* 5*d.* for each Life-Member.

During the Session 1915–16 the Society has lost by death one Honorary Member, Dr. E. Ludwig; one Past-President and Trustee, Dr. R. H. Scott; one Past-Foreign Secretary, Prof. J. W. Judd; one of the founders of the Society, Mr. J. H. Collins; and one Ordinary Member, Mr. T. J. Gibb. One Ordinary Member has been elected. The total number of Members on November 6, 1916, was 138, of whom fifteen are Honorary. Of the Ordinary Members fifty-one are Life-Members.

The Council has to congratulate the Society on its continued scientific activity and prosperity during the war.

On the motion of Mr. Ashcroft, seconded by Mr. Hutchinson, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried.

The dates of meeting for 1917, proposed by the Council, were approved.

An addition to the Bye-laws to the effect that Trustees of the Society shall be *ex officio* Members of Council was carried.

The following papers were then read:—

1. The combination of twin operations: by Dr. J. W. Evans.
2. The basalts of Hare Island, West Greenland: by Mr. A. Holmes.

3. Modification of the Kohlrausch method of determining refractive indices: by Dr. J. W. Evans.

A series of crystal models was exhibited and described by Miss N. Hosali.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 16, 1917, *at* 4.30 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

Dr. H. F. Harwood was provisionally elected an Ordinary Member of the Society.

The death of Mr. A. K. Barnett, an original Member, was announced.

Prof. C. G. Cullis and Mr. A. Holmes were elected Auditors of the accounts for the year ending December 31, 1916.

A sub-committee consisting of the Secretary, the Editor, Messrs. Barker, Evans, Hutchinson, and Watts, was elected to prepare a scheme for the preparation of abstracts from the leading journals.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 16, 1917, *at* 5.30 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

Seventeen Members and one Visitor were present.

The election of Dr. H. F. Harwood as an Ordinary Member of the Society was confirmed.

The following papers were read:—

1. The basalts of Iceland, the Faroes, and Jan Mayen: by Mr. A. Holmes, with analyses by Dr. H. F. Harwood.

2. The use of the orthographic projection in crystallography: by Prof. H. Hilton (p. 122).

3. Palaeophysiology: the organic origin of some minerals occurring in sedimentary rocks: by Prof. J. V. Samoilov (p. 87).

4. On Tapiolite in the Pilbara goldfield, Western Australia: by Mr. E. S. Simpson (p. 107).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 20, 1917, *at* 5 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

The audited balance-sheet for the year ending December 31, 1916, was approved.

The resignation of Mr. J. B. Scrivenor was accepted.

The Editor reported that he had sufficient material for a new number of the Journal, and it was resolved that he should proceed with its preparation.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 20, 1917, *at* 5.30 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

Fifteen Members and one Visitor were present.

The following papers were read:—

1. The basaltic rocks of Spitzbergen and Franz Josef Land in relation to the Brito-Arctic province: by Mr. A. Holmes, with analyses by Dr. H. F. Harwood.

2. A general proof of the limitation of the symmetry-numbers of crystals: by Dr. J. W. Evans.

3. The numerical relation between zones and faces of a polyhedron: by Prof. E. S. Fedorov (p. 99).

4. The crystallization of Parahopeite: by Messrs. A. Ledoux, T. L. Walker, and A. C. Wheatley (p. 101).

MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1916.

Receipts.	£ s. d.	£ s. d.
Balance from 1915—		
Bank (credit)	75 8 6	
Office (debit)	4 3 1	
		71 5 5
Subscriptions—(1) current	46 4 0	
(2) arrears	19 19 0	
(3) advance	3 3 0	
		69 6 0
Sale of publications—		
By Publishers	20 8 2	
„ G. Savigar	2 15 6	
		23 3 8
Dividends, War Loan		31 9 2
Repayment of Income Tax		12 18 8
		£208 2 11

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 82)	58 9 7	
Authors' copies	7 10 0	
Illustrations	2 14 0	
		63 13 7
Printing Postal Wrappers		1 0 0
Miscellaneous Printing (Williams & Strahan)		8 3 7
Editor's Honorarium (1915)		10 10 0
G. Savigar for care of Stock (1915)		1 1 0
Porter's Fee at meetings		1 0 0
Fee for manipulating lantern (1915)		1 0 0
Postage and Parcels—		
Magazine	2 14 2	
G. Savigar (1915)	5 11	
Hon. Secretary (1915)	8 7	
Hon. Treasurer (1915)	10 4	
		3 19 0
Bank Charges		3
Balance at Bank	118 3 11	
Less Office debit	8 5	
		117 15 6
		£208 2 11

Examined and compared with the vouchers, and found correct.
3 *March*, 1917.

(*Signed*) C. GILBERT CULLIS, ARTHUR HOLMES } Auditors.

BALANCE SHEET.

DECEMBER 31, 1916.

LIABILITIES.	£	s.	d.
Owing for Editor's Honorarium (1916)	10	10	0
,, G. Savigar for care of stock of Publications (1916)	1	1	0
,, Do. for postage (1916)		6	11
,, Hon. Secretary for postage (1916)		8	6
,, Hon. Treasurer for postage (1916)		10	8
,, fee for manipulating lantern (1916)	1	0	0
Excess of assets over liabilities	925	5	5
	£939	2	6

ASSETS.	£	s.	d.	£	s.	d.
Balance at Bank	118	3	11			
Less debit Balance in Office		8	5			
				117	15	6
War Loan, £798 8*s.* 4*d.* (valued at 97½)				778	18	6
Sale of Publications (1916)—						
Owing from Publishers	20	15	6			
,, G. Savigar	1	13	0			
				22	8	6
Arrears of Subscriptions (56) valued at				20	0	0
				£939	2	6

Number of Life Members, 49.

The stock of Publications and the value of the Library are not included in the above assets. (*Signed*) WM. P. BEALE,
Hon. Treasurer.
3 March, 1917.

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 84. June, 1917. Vol. XVIII.

Palaeophysiology: the organic origin of some minerals occurring in sedimentary rocks.

By J. V. Samoilov (Я. В. Самойловъ),
Professor of Mineralogy in the High School of Agriculture, Moscow.

[Read January 16, 1917.]

DURING the last few years I have applied myself to the study of some minerals occurring in the sedimentary rocks of a definite geological horizon. The success of my investigations was greatly favoured by the fact that the mineralogical material was collected during the course of the systematic geological exploration of the phosphate deposits of Russia, which during the past eight years has been under my immediate supervision.[1]

The explorations just mentioned were begun in the north-eastern part of European Russia, and several occurrences of barite were found in the first year during the field study of the phosphate deposits in the government of Kostroma. These barite deposits are associated with the Upper Jurassic strata, namely with the Oxfordian-Sequanian horizon. Such a definiteness in their stratigraphical position especially attracted

[1] 'Report on the geological investigations of the phosphate deposits' (Russ.), edited by Prof. J. Samojloff, 1909–1915, vols. i–vii.

my attention, and it was with much interest that I began to study the available material. During the second year of our geological investigations several other occurrences of barite deposits were met with, and all of them were found to belong to the same geological horizon. On the other hand, the most minute examination of the mineralogical material derived from other horizons failed to detect the presence of barium sulphate in any one of them.

The material so collected enabled me to describe[1] the barite deposits of the following nine localities: (1) Usole village on the Unzha river (left affluent of the Volga), (2) Dmitrieva village on the Unzha river, (3) Obrosimova village on the Nelsha river (left affluent of the Neya), (4) Fedikova village on the Neya river (right affluent of the Unzha), (5) Pogost village on the Neya river, (6) Tykolovo village on the Neya river, (7) Ogginetz village on the Gelvat river (left affluent of the Volga), (8) Dolgovo village, near Navoloki village, west of Kineshma, (9) Pushkino village, S.W. of Kostroma.

At these localities the barite is included in clay beds, and appears either in the form of very characteristic nodules, or else as a filling of the interstices and the cracks for the most part in marly septaria and sometimes in phosphatic concretions. In the article bearing on this subject I have given a detailed mineralogical account of all the barite deposits developed in the localities indicated above. These deposits are scattered over a large area, extending over 120 kilometres in a latitudinal direction and 100 kilometres in a meridional direction, and comprising parts of the districts of Kologriv, Makariev, Kineshma, and Kostroma in the Kostroma government.

Of course there are no reasons to believe that the occurrence of barite deposits in this part of the Kostroma government is confined to the places just mentioned; on the contrary, if we bear in mind that the samples of heavy-spar were being collected more or less accidentally, and that in the course of our field investigations our attention was directed to a wholly different problem, we must concede that it is obviously safer to infer that we have here a vast region where barite deposits are developed. Further, for this region the discovery of heavy-spar in a stratum gave evidence as to the age of this stratum, serving to some degree as a distinctive indicator or 'fossil'.

Covering, as time went on, a larger area, our investigations of the

[1] J. V. Samoilov, 'The deposits of heavy-spar in the east part of the government of Kostroma' (Russ.), Bull. Acad. Sci. Petrograd, 1910, vol. iv (2), pp. 857–880.

phosphate deposits extended south-eastward into the territory of the Kazan government. And here, too, near the Ozernoe Abyzovo village in the Yadrinsk district (at the boundary with the Kurmysh district of the Simbirsk government), heavy-spar was met with in the large marly nodules embedded in the clays of the Sequanian horizon.[1] In the Tetiushi district, 120 kilometres farther S.E. in the Baikovka village, there have been again encountered spherical marly concretions, associated with a similar heavy-spar, which has not yet been described in detail. These newly-encountered occurrences of barite are situated at a considerable distance, about 250 kilometres, from the area of development of the Oxfordian-Sequanian heavy-spar of Kostroma. Nevertheless they present the same characteristics and belong to the same geological age as those of Kostroma.

All these observations recall the old data concerning the discovery of barite on the banks of the Sura and Piana rivers, where too the Sequanian clay beds are developed ('Schwerspathbälle am Ufer der Sura und Piana').[2] The region of these two rivers is situated at a comparatively short distance from the area occupied by the barite deposits of Kostroma, and it seemed highly probable that these 'Schwerspathbälle' were enclosed in the same horizon. And two years ago in the course of our phosphate field-work heavy-spar enclosed in Sequanian marls was discovered at several localities, namely near the Sobatshy Ostrov village, in a ravine cutting the right bank of the Malaja Medjanka river, and near the Radova village on the left side of Sura river. Further, barite has been discovered in the same locality near the Ratova village in phosphatic nodules embedded in grey, marly clays of a rather later age—namely of that of the Kimeridgian. Associated with strata of this last horizon, heavy-spar was encountered also at the Mineshino village, in a ravine opening into the valley of Piana river, and near the Riapino village situated on the left bank of the Sura and Menja rivers.

Thus the age of the sediments enclosing barite deposits must be somewhat extended (Oxfordian-Kimeridgian). It may be noted here that in the above-mentioned regions of the Kazan and Kostroma governments deposits of the Kimeridgian horizon do not attain such development as in the Kurmysh district of the Simbirsk government.

[1] J. V. Samoilov, 'On the distribution of the Oxfordian-Sequanian barites in the eastern part of European Russia' (Russ.), Bull. Acad. Sci. Petrograd, 1912. vol. vi (2), pp. 939–944.

[2] J. G. Georgi, 'Geographisch-physikalische und naturhistorische Beschreibung des Russischen Reiches,' Königsberg, 1798, Theil iii, p. 142.

Some years ago in a work treating with the subject of the crystallography of barite I described[1] crystals obtained from the deposits of this mineral lying in a remote region of north-eastern Russia, namely from the region of the Izhma river and of its tributary the Ukhta, in the basin of the Pechora river. This barite is very like some of that of the Kostroma government; it is enclosed in nodules embedded in dark Jurassic clays. At that time the exact geological age of these dark clays did not interest me, but if now we endeavour to answer this question we could with a great degree of probability, according to our present knowledge of the Jurassic beds in this remote region, assign these barite deposits like those already examined to the clay beds of Oxfordian-Kimeridgian age.

There are thus barite deposits distributed over a comparatively large area and belonging to a quite definite geological age.

The petrographical character of the Upper Jurassic and Lower Cretaceous beds covering this region is now well known (with the exception of the region of the basin of the Pechora river), as a result of the geological investigations mentioned above. This petrographical character cannot afford any explanation as to the presence of barite deposits in this series. It is difficult, therefore, to admit here the supposition of the secondary origin of the barite, though it is common to resort to such an explanation in cases of a similar mode of occurrence of various minerals.

Under these circumstances I have ventured to suggest that these barite deposits are of primary origin, having been deposited together with the materials which gave rise to the enclosing sedimentary rocks.[2]

The Oxfordian-Kimeridgian clays, which include the heavy-spar, are of marine origin, and the question naturally must arise whether barite deposits are met with in the contemporaneous sediments of the sea-floor. Our knowledge in this respect is very scanty, but we have nevertheless the interesting data of Jones,[3] concerning the discovery of heavy-spar nodules on the sea-floor from dredgings at a depth of 675 fathoms near Colombo. This abyssal barite in its external appearance, composition,

[1] J. Samoilov, 'Materials towards the crystallography of barite' (Russ.), Bull. Natur. Moscou, 1902, vol. xvi, p. 228.

[2] Recently K. André (Neues Jahrb. Min., 1914, Beil.-Bd. xxxvii, p. 343) and A. Bergeat (Zeits. prakt. Geol., 1914, vol. xxii, p. 237) mention the primary mode of origin of celestite and barite deposits.

[3] E. Jones, 'Examination of nodular stones obtained by trawling off Colombo,' Records Geol. Survey India, 1888, vol. xxi, p. 35.

and to some extent in its microscopical structure presents characters strikingly similar to those of the Russian occurrences mentioned above. In fact the descriptions given by Jones would apply equally well to the nodules from, for example, Tykolovo and Pogost in the Kostroma government.

It can be admitted, therefore, that barium sulphate was deposited on the floor of the Oxfordian-Kimeridgian ocean in the north-eastern part of Russia.

I do not intend to dwell just now on the details of the question concerning the proportion of barium in ocean waters and in marine sediments. Data bearing on this subject can be found in the works of Forchhammer,[1] of Sir J. Murray and A. F. Renard[2] (barium contained in a sample of diatom-ooze and traces of barium in the globigerina-ooze), of F. W. Clarke[3] (analysis of terrigenous deposits—blue and green muds, and red clays). It may only be noted here that in the contemporaneous epoch, as in the previous geological times, the barite nodules are not to be found universally over the sea-floor, and that their distribution is evidently controlled by certain conditions peculiar to the different regions. I would venture to raise the question whether these conditions are not to be searched for in the peculiarities of the fauna and flora of the region, and whether there might not exist organisms which would contain barium in the substance of their shells or of their bodies. Were this the case, it could be assumed that the accumulation of the remains of such organisms on the bottom of the sea would have had as a result the enrichment in barium of the corresponding marine deposits. The subsequent diagenetic processes would tend to concentrate into separate nodules the stable compound of barium, namely the sulphate.

Turning to the literature we find, however, a remarkable scarcity of data regarding this subject. All we know is limited to some, not numerous, indications as to the presence of barium in the ash of marine plants and animals, of which a *résumé* is given by Quinton.[4] At the same time it must be borne in mind that in general our knowledge of the chemical composition of the skeletons of marine organisms is being

[1] G. Forchhammer, Phil. Trans. R. Soc. London, 1865, vol. clv, p. 213.

[2] J. Murray and A. F. Renard, Report on deep-sea deposits (Challenger Expedition), 1891, pp. 437 and 446.

[3] F. W. Clarke, Proc. R. Soc. Edinburgh, 1907, vol. xxvii, pp. 167 and 269; also Journal of Geology, 1907, vol. xv, p. 783.

[4] R. Quinton, 'L'eau de mer milieu organique,' Paris, 1904, p. 310.

very slowly increased,[1] and that we often meet in zoological works with the complaint about the almost total absence of precise chemical analyses of the skeletal parts of organisms.

The hypothesis which at first suggested itself to me assumed the existence of organisms capable of taking up and concentrating barium; but at that time no such organisms were as yet known to me. For this reason I had to content myself only with the analogy, the principal ground for which I had in the fact of the presence, according to O. Bütschli,[2] of sulphate of strontium in the skeletal substance of one group of Radiolaria, namely that of the Acantharia. It will be clear, therefore, with what a keen interest I read the recent works of F. E. Schulze[3] and A. Chepotiev[4] concerning a particular group of Rhizopods—namely that of the Xenophyophora. This group was established by Schulze, who worked out a portion of the zoological material collected by the German 'Valdivia' expedition, the Dutch 'Siboga' expedition, and the American 'Albatross' expedition; moreover, all the material of the 'Challenger' expedition was at his disposal.

In the bodies of these Xenophyophora there are some peculiar formations, which Schulze called 'Granellen'. These he describes as small, lustrous, quite colourless and transparent, rounded, oblong or fusiform bodies, with a high refractive index and low birefringence. The size of the 'Granellen' varies between 1–6 μ. They are represented by Schulze in his Plate II, figs. 2, 4, 11, &c. The chemical analysis proved that they are composed of barium sulphate ($BaSO_4$). In order to verify this fact, Schulze handed the 'Granellen' for investigation to the professor of physiological chemistry, Thierfelder, who confirmed the accuracy of the first analysis. According to Thierfelder,[5] they consist of barium sulphate with a very small quantity of calcium sulphate. One can agree with Schulze that this fact constitutes an 'auffällige und überraschende Tatsache'.

[1] Quite recently there have been published the articles of F. W. Clarke and W. C. Wheeler, containing analyses of Brachiopod shells and of Alcyonaria. Proc. Nat. Acad. Sci. Washington, 1915, vol. i, pp. 262 and 552.

[2] O. Bütschli, Zoologischer Anzeiger, 1906, vol. xxx, p. 784.

[3] F. E. Schulze, Wissensch. Ergebnisse d. deutsch. Tiefsee-Expedition auf d. Dampfer 'Valdivia', 1905, vol. xi, Lief. 1, p. 14.

[4] A. Chepotiev, 'Explorations of low organisms' (Russ.), Petrograd, 1910, pp. 2, 7.

[5] H. Thierfelder, Sitzungsber. Gesellsch. Naturforsch. Freunde, Berlin, 1905, No. 1, p. 4.

As to the distribution of the Xenophyophora, Schulze[1] in one of his papers gives a detailed list of all the localities where these interesting animals have hitherto been met with. He enumerates thirty-three such localities; three of them in the Atlantic Ocean, six in the Indian Ocean, and twenty-four in the Pacific. Only five of these localities are situated in subtropical regions, and the remainder in the tropics. The depth at which Xenophyophora have been found is very great, the average depth of their occurrence being about 4,000 metres. Only in one place of the Pacific have these animals been met with at a depth of 981 metres.

Chepotiev also gives some interesting data, which extend considerably the region where these animals are met with. This author has found representatives of the group of Xenophyophora amongst the coral-reefs bordering the northern end of Ceylon, on the shore of the Palk's Strait, where he found them at very low ebb, at a depth of only 1–5 metres. Chepotiev has observed 'Granellen' of a greater size (from 1 to 25 μ in length), appearing in the form of more regular crystals of the same shape as the 'Granellen' of the abyssal Xenophyophora (see Chepotiev, Plate II, figs. 13 and 14). This occurrence of Xenophyophora off the coast of Ceylon becomes especially interesting in connexion with the fact that the only heavy-spar nodules hitherto obtained from the sea-bottom by dredging come, as already mentioned, from the vicinity of Colombo.

Thus, owing to the observations just cited, the problem regarding the presence of barium sulphate in the bodies of some marine organisms can be recognized as solved. It will, of course, fall to the task of specialists to grasp the full physiological meaning of the fact under consideration. I need here only point out its mineralogical importance, which is especially great in connexion with the question of the primitive origin of minerals. To the list of the types of barite deposits already known must now be added a new type—namely that formed by the accumulation of the remains of marine organisms belonging to the group of Xenophyophora.[2]

With the study of minerals included in sedimentary rocks it is of particular importance from the present point of view to give an exact geological description of the strata containing the minerals under consideration ('stratigraphical' mineralogy), and to solve, as far as possible,

[1] F. E. Schulze, Sitzungsber. Gesellsch. Naturforsch. Freunde, Berlin, 1906, No. 8, p. 205.

[2] J. V. Samoilov, 'On sulphate of barium in animal bodies' (Russ.), Bull. Acad. Sci. Petrograd, 1911, vol. v (1), p. 475.

the question regarding the genetic relations of these minerals, i. e. whether they are of primary or of secondary origin.

Owing to my great interest in these questions I have recently taken up the study of another mineral closely related to barite—namely that of the celestite deposits of Turkestan. Thanks to the kind attention of several geologists engaged in the geological mapping of this region, I have at my disposal specimens of celestite derived from the deposits of this mineral discovered in the following ten different localities: (1) the vicinity of Suzak village, situated on the left side of the Kugart-su river (right tributary of the Kara-Darya river), 45 kilometres eastward from the town of Andizhan; (2) a place lying at 170 kilometres to the westward from the first locality, namely Kamuish-bashi, Kokand district; (3) Sel-Rokho, at a distance of nearly 35 kilometres westward from the last-mentioned locality, Kokand district; (4) at a distance of 250 kilometres to the S.S.E., in the basin of the Obi-niou river (right tributary of the Pyangy river), Garmak village, Kuljab district, in eastern Bucharia; (5) at a distance of 200 kilometres from the town of Shirabad; (6) Kukcha hill, lying at a distance of 60 kilometres to the N.E. of the town Petro-Alexandrovsk; (7) nearly 350 kilometres to the E.N.E., the island of Nicholas I on the Sea of Aral; (8) Chagabulak; (9) Udyuk, situated at a distance of nearly 30 kilometres westward from Tyube-Kuduk; (10) the mountain Ungozya at a distance of 4 kilometres from the Saruitash gulf. The three last-named localities are situated on the Manguishlak peninsula.

These celestite deposits are distributed over a vast area, extending from eastern Fergana to the coast of the Caspian Sea, and from the southern part of eastern Bucharia to the shores of the Sea of Aral. From the detailed description,[1] which I have already given in the Russian language, of these deposits, it can be realized how very accidental has been their discovery. No special efforts have been made to find the mineral, the explorers being engaged on a wholly different problem, and only occasionally happening to take up a specimen of a mineral unfamiliar to them. Consequently it may with confidence be inferred that the question regarding the local development of the celestite deposits in Turkestan is not in the least degree exhausted by the above-quoted enumeration of the places of its occurrence. It might be affirmed, on the contrary, in a region like Turkestan,

[1] J. Samoilov, 'On the genesis of some minerals occurring in sedimentary rocks.—Celestite of Turkestan,' Materials towards the exploration of the geological structure of the Russian Empire (Russ.), Moscow, 1914, p. 219.

standing as yet on the threshold of geological investigation and presenting in its greatest part a desert, that these accidental discoveries of celestite point undoubtedly to a vast distribution of strontium sulphate. Unfortunately, all of the celestite deposits of Turkestan are as yet not characterized from the geological point of view with the desired completeness. In some cases the age of the celestite-containing strata cannot be made out with sufficient exactitude; in other cases there are no reliable data for solving the question as to the primary or secondary origin of the mineral. We must, therefore, content ourselves with the general statement that almost the whole of the celestite deposits of Turkestan belong to the Upper Cretaceous formation.

Turning now to the sources of strontium which gave rise to the numerous celestite deposits of Turkestan, I venture to put forward the suggestion that the immediate source may be looked for in the accumulation of this metal by organisms. Some data relative to the presence of strontium in the skeletal parts (the shells) of animals of various kinds may be found in the literature (see, for example, O. Vogel[1]). The valuable paper of Bütschli on the presence of strontium sulphate in the skeletons of the Acantharia has already been quoted above. It might be conjectured that there were, among the living forms of the Cretaceous sea, organisms containing a relatively large amount of strontium, and that the relative abundance of this alkaline-earthy metal in the Cretaceous sediments may be attributed to the existence of such organisms.

I conjecture a similar mode of origin in reference not only to the barium and strontium sulphates, but likewise to a number of other minerals occurring in sedimentary rocks. As is commonly known, the ocean waters contain a great many chemical elements in solution, but the proportion of many of these elements in sea-water is extremely small. A concentration of them to such an extent as to give rise to solid deposits would be therefore impossible under ordinary conditions, and a special apparatus is required, which would be able to accumulate such finely diffused matter. According to my opinion, such an apparatus is provided in the form of vegetable and animal organisms, which have the capacity of taking up the material indispensable for their existence even when this material is in a state of extreme dissemination. In such cases we have to deal therefore not with a simple chemical, but with a chemico-biological process.

[1] O. Vogel, Zeits. Anorganische Chemie, 1894, vol. v, p. 42.

Studying chiefly the morphological features of the fossil organisms palaeontology affords a clear understanding of those great changes to which the morphological structure of the organisms are subject. In the most recent times this science has made a step farther, and is now studying the problems of palaeobiology.[1] In this connexion we may consider whether physiological processes have revealed some changes as time went on. I mean, not the character of the physiological processes, but their intensity, and especially the materials with which these processes had to deal. An example will serve better for the elucidation of my meaning.

The blood of the animal organisms has always had to accomplish its essential, strictly determined function, and we know what a share in the fulfilment of this function is to be attributed to the iron contained in the blood of contemporaneous animals; but the same importance could conceivably be acquired by some other metal, for instance by copper. At present we have a not very extensive list of animals in the blood of which iron has been supplanted by copper; this list comprises those animals (e. g. amongst the Crustacea and Mollusca) the blood of which contains haemocyanin. And I think that it might reasonably be suggested that the quantitative relation between the animals containing as a constitutive part of their blood haemoglobin, on the one hand, and those containing haemocyanin, on the other, has not always been the same as it is in the present period of the earth's history. Have there not been periods in the earth's history when amongst the animals then existing those containing haemocyanin in their blood predominated?

As is commonly known, the chemical analysis of the ash of different kinds of plants sometimes reveals elements, the presence of which is quite unexpected and the proportion of which is exceedingly small. But has the relative amount of the various elements constituting the ash of plants always been the same, and have there not been past geological periods when plants of quite a different ash-composition prevailed?

We are entering here quite a new and unknown region, for the designation of which I should suggest the term of 'palaeophysiology' as the most suitable. For the solution of the questions involved there is, of course, no direct method, because the use of the evidence supplied by the fossil remains themselves is not available in the study of such problems. And yet the elucidation of these questions might afford a better understanding

[1] O. Abel, 'Grundzüge der Palaeobiologie der Wirbeltiere,' Stuttgart, 1912.

of the genesis of some mineral deposits, the origin of which has remained hitherto very obscure.[1]

Let us now direct our attention to the particular case suggested by haemocyanin. The origin of the copper deposits of the Permian formation has given and still gives rise to much controversy. This metal occurs in the Permian sediments either as disseminated minerals or as deposits of economically valuable copper ore. But it must be remarked that the general geological features of the regions where copper-bearing beds occur are far from being similar. There is only one thing remaining constant in all these copper-containing sediments, that is, their belonging to the Permian age. And it is in this direction that the key to the genesis of these deposits must be searched for. If we admit that animals with haemocyanin in their blood prevailed during the Permian period, the question regarding the origin of the copper deposits will receive a new aspect. The presence of copper in the Permian sediments will appear quite natural and even necessary: it will only point to the development of a similar Permian fauna. The enrichment of some of the Permian sediments in copper will stand in connexion with the abundance of the fauna in the corresponding region during the Permian period. The presence of a rich fauna in the more extensive copper deposits of the Permian age has already been frequently observed; but hitherto it has been believed that the rôle of this fauna was confined to its reducing action on solutions of copper salts. I attach much more importance to this fauna, and I regard it as the source itself which gave rise to the copper deposits. I believe that the vital action of organisms caused the accumulation of copper secreted from the ocean waters.

On every occasion when there can be established the special association of a mineral with some definite geological horizon, it is necessary, according to my opinion, to examine closely the question whether the formation of this mineral could not possibly have been connected with the action of organisms.

The deficiency of our knowledge with regard to the chemical composition of contemporaneous animals is very much hindering the progress of the investigation of this problem. Indeed, it has not been supposed until quite recently that there were animals the skeletons of which consist

[1] Based on the evidence of the chemical components of vegetable and animal protoplasm, A. B. Macallum adduces interesting considerations regarding the composition of the sea-water in past geological periods (Trans. Canadian Institute, Toronto, 1904, vol. vii, Part 3, No. 15, p. 535).

of sulphate of strontium. Not less unexpectedly came the discovery of the group of marine animals Xenophyophora, the bodies of which contain grains of sulphate of barium. A paper has recently been published[1] which establishes the presence of vanadium in the blood of certain animals, namely the Ascidia (or Phallusia), in which it performs the same function as iron. A recent paper by A. E. Boycott,[2] 'On the occurrence of manganese in land and fresh water mollusca,' refers to earlier work by H. C. Bradley[3] on the same subject.[4]

It would scarcely be reasonable to suppose that all the facts concerning this problem are restricted to those so recently and so unexpectedly discovered, and that we are not standing before some new and not less remarkable discovery. But even remaining within the limits of the facts already established, we must concede that a thorough mineralogical elucidation of the nature of this accumulation of strontium, barium, copper, and vanadium through the agency of vital processes should be considered seriously. And when we admit that the various organisms characterized by these unusual properties, although less numerous in the contemporaneous epoch, might have been more abundant and appear as a common and widespread group at some remote period of the earth's history, it will be clear then what importance must be attached to the detailed elucidation of all these questions for the proper understanding of the genesis of various minerals occurring in sedimentary rocks.

Institute of Mineralogy,
High School of Agriculture,
Petrovsko-Razumovskoye, near Moscow.

[1] M. Henze, Zeits. physiolog. Chemie, 1911, vol. lxxii, p. 494.

[2] A. E. Boycott, Naturalist, London, 1917, pp. 11–18, 69–73.

[3] H. C. Bradley, Journ. Biological Chemistry, 1907, vol. iii, p. 151; 1910, vol. vii, p. 237.

[4] There are, thus, in the blood of different kinds of animals the following metals: iron, manganese, copper, and vanadium. But what have all these metals in common? They stand near to each other in their atomic weight in the following order: V = 51, Cr = 52, Mn = 55, Fe = 56, Co = 59, Ni = 59, Cu = 63. Perhaps, as the result of further investigations, there will be discovered organisms whose blood contains metals occupying the intervals in the range just adduced, namely chromium, cobalt, and nickel.

The numerical relation between the zones and faces of a polyhedron.

By E. S. Fedorov (Е. С. Федоровъ),
Professor of Crystallography in the Institute of Mines, Petrograd.

[Read March 20, 1917.]

IN Professor G. Cesàro's note[1] 'Sur une propriété numérique de l'ensemble des axes de symétrie situés dans les plans de symétrie d'un polyèdre' is given the formula ((1) on p. 174)

$$X^2 = X + (n-1)\Sigma N_1 + (p-1)\Sigma P_1 + (q-1)\Sigma Q_1 + \ldots$$

or $$(X-1)X = (n-1)\Sigma N_1 + (p-1)\Sigma P_1 + (q-1)\Sigma Q_1 + \ldots,$$

in which '$N.\Lambda^n$, $P.\Lambda^p$, $Q.\Lambda^q$,... est l'ensemble des axes de symétrie qu'un polyèdre contient dans ses plans de symétrie'. From the last-named condition it might appear that this formula is only applicable in the particular case when the axes of symmetry are the intersection-directions of planes of symmetry. It has, however, a wider and more varied application, and moreover is identical with the formula[2]

$$(p-1)p = 1.2f_2 + 2.3f_3 + \ldots + (n-1)nf_n + \ldots$$

which was deduced by the present author before 1880, and applied with two different significations.

If we term the product $m(m-1)$, where m is a whole number, 'the function' of this number, then the above formula in one of its significations is an expression of the theorem: *The function of a zonohedron is the sum of the functions of its faces.*

A 'zonohedron' is defined as a polyhedron whose faces lie in the primitive zones on the crystal, such, for example, as the cube or rhombic-dodecahedron. Its faces are polygons with an even number of sides in parallel pairs. The symbols $f_2 \ldots f_n$ in the above formula denote the

[1] G. Cesàro, Mineralogical Magazine, 1915, vol. xvii, pp. 173–177.

[2] E. S. Fedorov, 'Elements of the theory of figures' (Russ.), Verh. Russ.-Kais. Mineralog. Gesell. St. Petersburg, 1885, ser. 2, vol. xxi, pp. 1–277, with 18 plates. See §§ 65, 70 (formula on p. 192). Abstract in Zeits. Kryst. Min., 1893, vol. xxi, pp. 679–714 (formula on p. 689).

number of faces with n pairs of parallel edges (two parallel faces being regarded as identical), and p means the number of zones. For the cube $p = 3$ and $f_2 = 3$; introducing these values into the formula we get $2.3 = 1.2.3$. For the rhombic-dodecahedron we have $p = 4$ and $f_2 = 6$; thus $3.4 = 1.2.6$. It was on this account that the formula was termed 'zonohedral'.

In its second signification the formula implies a corresponding theorem, relating to a polyhedron with parallel faces. The theorem can be stated as follows: *The function of a paired-faced polyhedron is the sum of the functions of its zones.*

Here the formula is termed 'polar zonohedral'; and p is now the number of pairs of parallel faces, and f_n is the number of zones passing through n pairs of parallel faces. For the octahedron $p = 4$, $f_2 = 6$; thus $3.4 = 1.2.6$. For the rhombic-dodecahedron $p = 6$, $f_2 = 3, f_3 = 4$; thus $5.6 = 1.2.3 + 2.3.4$.

In neither case does the formula bear any relation to symmetry. But in the very special case, dealt with by Cesàro, in which axes of symmetry are the intersections of planes (P) of symmetry, we have a polyhedron with the number of faces $2P$; and for each zone with axes Λ^2, Λ^3, Λ^4 we have $f_2 = 2, 3, 4$ respectively. Thus in the case $3\Lambda^2$, $4\Lambda^3$, we have $P = 6$, and $5.6 = 1.2.3 + 2.3.4$; in the case $6\Lambda^2$, $4\Lambda^3$, $3\Lambda^4$, we have $P = 6 + 3$, and $8.9 = 1.2.6 + 2.3.4 + 3.4.3$; and in the case of the *regular* dodecahedron $15\Lambda^2$, $10\Lambda^3$, $6\Lambda^5$, we have $P = 15$, and $14.15 = 1.2.15 + 2.3.10 + 4.5.6$.

The crystallization of Parahopeite.

By A. Ledoux, T. L. Walker, and A. C. Wheatley.

[Read March 20, 1917.]

THIS species, a hydrous zinc phosphate, $Zn_3P_2O_8 . 4H_2O$, dimorphous with hopeite, was first described by Spencer in 1907.[1] While the material then available was suitable for the physical and chemical description of the new mineral, it did not permit a full crystallographic investigation. Spencer noted that the crystals resembled in a general way those of hemimorphite, and made sufficient measurements to indicate the triclinic character of the mineral. In his sketch of a crystal he indicates that the mineral is twinned, and that this twinning is best seen on the perfect cleavage which is parallel to the brachypinacoid.

Recently some very fine specimens of this mineral from the Broken Hill mines, North-Western Rhodesia, the type locality, were obtained by the Royal Ontario Museum of Mineralogy. The following crystallographic description of parahopeite is based on this material. The crystals are prone to form groups in approximately parallel position, but by careful search a number of simple crystals or of groups in which the individuals are in twinned relationship to each other were obtained. These are very small—usually not more than two millimetres long, one millimetre broad, and one-half millimetre thick. We find that the crystals are triclinic with the macropinacoid (100) as twinning-plane and composition-face. The elements derived from measurements are as follows:

$$a : b : c = 0{\cdot}7729 : 1 : 0{\cdot}7124;$$
$$\alpha = 93° 22', \ \beta = 91° 12', \ \gamma = 91° 22'.$$

The faces most prominent on the crystals are the pinacoids (100), (001), and (010); the pyramids $(1\bar{1}1)$, $(\bar{1}\bar{1}1)$, and (322); the prisms (110) and $(1\bar{1}0)$; and the domes $(0\bar{1}1)$, $(0\bar{1}2)$, and (011), fig. 1. The

[1] L. J. Spencer, Mineralogical Magazine, 1908, vol. xv, p. 18.

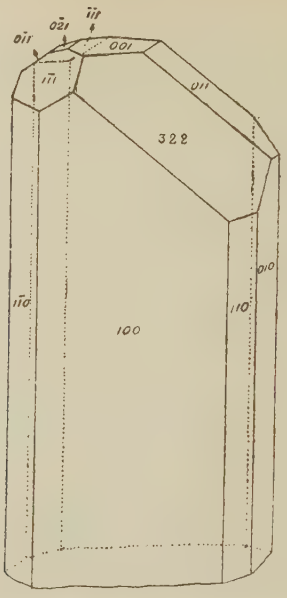


FIG. 1.—Crystal of Parahopeite showing the principal forms.

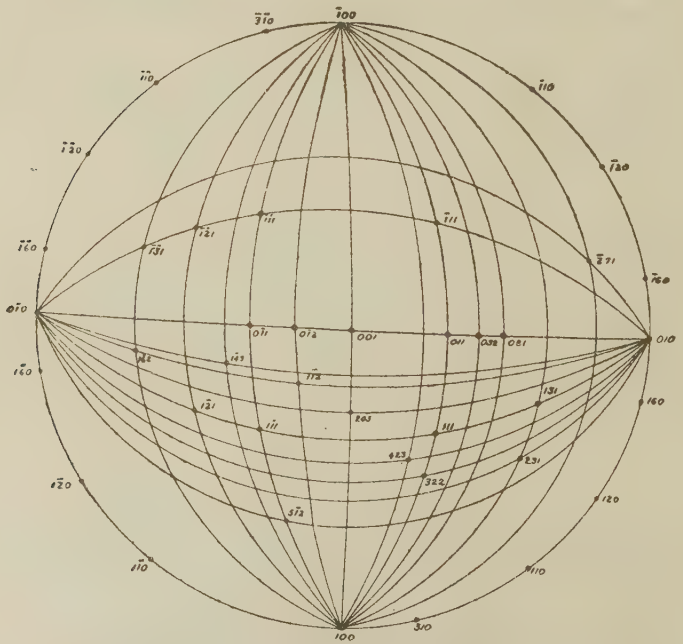


FIG. 2.—Stereographic projection showing all the forms observed on Parahopeite.

three pinacoids, the two unit prisms, and the pyramid (322) are so much more prominent than the other forms that they are responsible for the general habit of the crystals. The following forms, thirty-two in number, have been definitely established from our observations:

Pinacoids—(100), (001), (010);
Prisms—(310), (110), (120), (160), (1$\bar{1}$0), (1$\bar{2}$0), (1$\bar{6}$0);
Brachydomes—(021), (032), (011), (0$\bar{1}$2), (0$\bar{1}$1);
Macrodomes—(203);
Pyramids—(111), (1$\bar{1}$1), ($\bar{1}$11), ($\bar{1}\bar{1}$1), (423), (131), (231), (322), (1$\bar{1}$2), (1$\bar{2}$1), (5$\bar{1}$2), (1$\bar{4}$3), (1$\bar{6}$2), ($\bar{2}$71), ($\bar{1}\bar{2}$1), ($\bar{1}\bar{3}$1).

Certain of the preceding forms appear as very small faces, so that there is a considerable difference between the measured and calculated angles, but as the most of them have been observed on more than one crystal, it is our opinion that their position should be regarded as established. This applies particularly to (111), (131), (310), (160), (1$\bar{1}$2), (5$\bar{1}$2), ($\bar{2}$71), (1$\bar{6}$0).

Measured and Calculated Angles for Parahopeite.

	Measured.	Calculated.	Difference.		Measured.	Calculated.	Difference.
	° ′	° ′	′		° ′	° ′	′
(100) (010)*	88 33	88 33	0	(423) (001)	51 20	51 29	− 9
(110) (010)	51 3	51 22	−19	(322) (001)	55 11	55 36	−25
(120) (010)	31 49	32 27	−38	(110) (001)	86 57	86 56	+ 1
($\bar{1}$20) (010)	33 29	33 17	+12	($\bar{1}\bar{1}$1) (001)	51 15	51 26	−11
($\bar{1}$10) (010)	53 18	53 9	+ 9	(231) (001)	67 40	67 44	− 4
(100) (001)*	88 43	88 43	0	($\bar{1}\bar{2}$1) (001)	61 52	62 33	−41
(010) (001)*	86 36	86 36	0	($\bar{1}\bar{2}$0) (001)	93 52	93 31	+21
(021) (001)	52 17	52 21	− 4	($\bar{1}\bar{3}$1) (001)	69 41	69 0	+41
(032) (001)	44 30	45 6	−36	(1$\bar{1}$1) (010)*	114 40	114 40	0
(011) (001)	33 53	34 18	−25	(021) (100)	87 35	88 9	−34
(0$\bar{1}$2) (001)	20 5	19 57	+ 8	(322) (100)	41 58	41 36	+22
(0$\bar{1}$1) (001)	36 18	36 35	−17	(011) (100)	87 44	88 10	−26
(1$\bar{6}$2) (001)	67 20	66 48	+32	($\bar{1}$11) ($\bar{1}$00)	55 3	55 6	− 3
(1$\bar{4}$3) (001)	45 30	46 13	−43	(1$\bar{1}$1) (100)*	52 13	52 13	0
(1$\bar{2}$1) (001)	60 53	60 48	+ 5	($\bar{1}\bar{1}$1) ($\bar{1}$00)	52 11	52 28	−17
(1$\bar{2}$0) (001)	91 38	92 11	−33	(1$\bar{4}$3) (0$\bar{1}$0)	50 24	49 53	+31
($\bar{1}$10) (001)	88 55	88 55	0	(1$\bar{2}$1) ($\bar{1}$00)	62 1	61 48	+13
($\bar{1}$11) (001)	47 59	48 22	−23	($\bar{1}\bar{2}$1) ($\bar{1}$00)	61 29	61 5	+24
(1$\bar{1}$1) (001)	49 22	49 35	−13	(1$\bar{6}$2) (0$\bar{1}$0)	28 40	29 24	−44
(203) (001)	31 21	31 11	+10				

	Measured.	Calculated.	Difference.		Measured.	Calculated.	Difference.
	° ′	° ′	° ′		° ′	° ′	° ′
(111) (001)	47 9	47 54	− 45	(1$\bar{1}$2) (100)	67 9	65 34	+1 35
(111) (100)	55 3	52 42	+2 21	(5$\bar{1}$2) (001)	68 10	68 21	− 11
(131) (001)	62 53	63 55	−1 2	(5$\bar{1}$2) (100)	22 47	21 45	+1 2
(310) (010)	73 8	74 10	−1 2	($\bar{2}$71) (001)	75 1	76 32	−1 31
(160) (010)	13 5	12 5	+1	($\bar{2}$71) ($\bar{1}$00)	73 53	72 6	+1 47
(1$\bar{1}$2) (001)	28 46	30 8	−1 22	($\bar{1}$60) (010)	11 4	12 12	−1 8

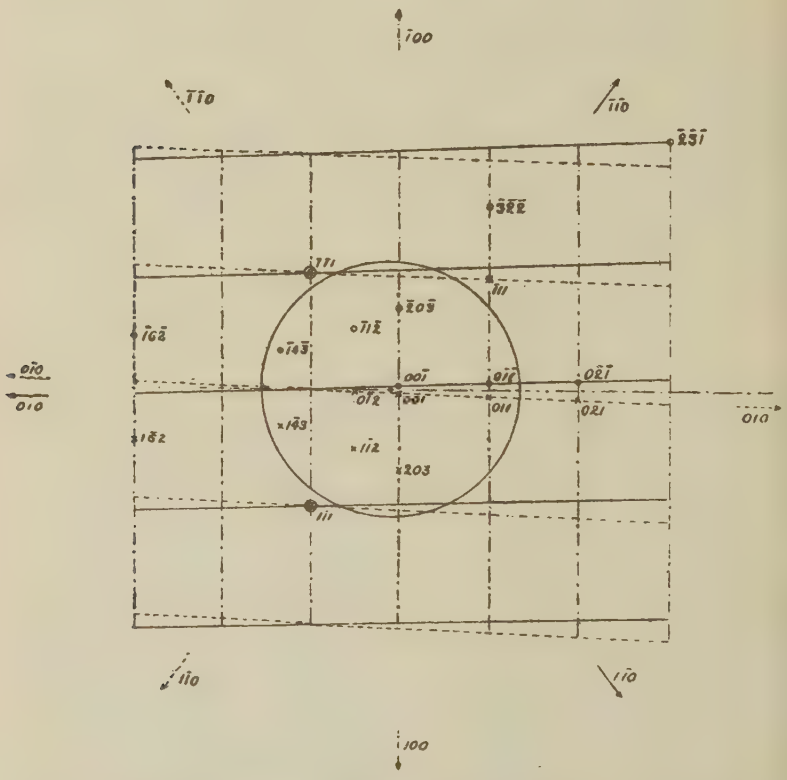


Fig. 3.—Gnomonic projection showing the faces observed on a twin-crystal of Parahopeite.

The angles marked thus * have been used for the calculation of the elements. Faces with poor reflections, giving differences of more than one degree between the measured and calculated values, are set apart at the end of the table.

All the forms observed on the ten crystals measured are indicated on the accompanying stereographic projection, fig. 2. The gnomonic projection, fig. 3, shows the faces observed on a twin-crystal, the twin-plane being (100). The faces belonging to one individual are shown by small rings, while those of the other are marked by small crosses.

On many of the twinned crystals measured most of the terminal faces belong to a single individual. This is explained by the fact that in cleavage plates parallel to the brachypinacoid the end of the crystal is frequently composed of a single individual, fig. 4 (and also shown in Spencer's fig. 4). In the prism-zone on such crystals, faces representing both individuals are frequent.

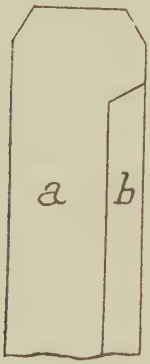


FIG. 4.—Sketch of cleavage plate of Parahopeite parallel to the pinacoid (010). On the upper end of the twin-crystal only one individual is present.

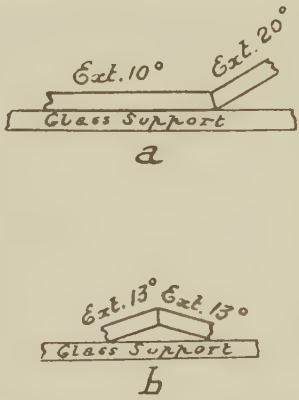


FIG. 5.—Sketches showing the relationship between extinction values measured on cleavage plates and the position of the cleavage with regard to the glass support.

Cleavage plates parallel to the brachypinacoid show lamellar twinning resembling that of plagioclase according to the albite law. Alternate individuals extinguish simultaneously just as in albite. Very varied extinction-angles have been recorded.[1] This is due to the absence of parallelism between the cleavage flake of the crystal individual and the glass support. When the plate measured lies so that the cleavage is parallel to the glass the extinction-angle is about 10° from the edge (100) (010). In this case the individual twinned with the first being

[1] Spencer, loc. cit., p. 20.

inclined to the glass support at an angle of about three degrees shows an extinction of about 20° to the same edge. If, on the other hand, both cleavages make equal angles with the glass support, the extinction of the two individuals is symmetrical at 13° with regard to the edge referred to. The true extinction-angle on a cleavage plate parallel to (010) is therefore 10°, and the other values are due to lack of parallelism between the glass support and the cleavage of the individual concerned (fig. 5).

Royal Ontario Museum of Mineralogy,
Toronto, Canada.

On Tapiolite in the Pilbara goldfield, Western Australia.[1]

By Edward S. Simpson, B.E., B.Sc., F.C.S.,

Government Mineralogist and Chemist, Geological Survey of Western Australia.

[Read January 16, 1917.]

THE Pilbara goldfield lies in the north-west division of Western Australia within the tropics, and has been described in considerable detail by A. Gibb Maitland in Bulletin 40 of the Geological Survey of Western Australia. Though the chief mineral product at present is gold, the district abounds in other economic minerals, notably ores of copper and tin, and has already become famous as being by far the most important producer of tantalum in the world, the chief source of supply of this metal being the manganotantalite of Wodgina.

The north-western portion of the Pilbara goldfield adjacent to th coast, and covering an area of about 100 miles (east and west) by 70 miles (north and south), is shown by A. Gibb Maitland's map to be occupied by an immense mass of granite, flanked and intruded by ancient greenstones. This area embraces the Wodgina mining centre and a number of other localities in which tantalum minerals have been found. These minerals are usually associated with detrital tin-ore, the source of both being traceable to pegmatite veins in which albite is frequently the preponderating constituent. The species and localities already recorded by the author[2] are:

Ferrotantalite: Greens Well.

Manganotantalite: Wodgina, Moolyella, Greens Well, Mt. Francisco, and probably Cooglegong.

Ferrocolumbite: Greens Well.

Manganocolumbite: Moolyella, Mt. Francisco, Cooglegong, Lalla Rookh (ferrocolumbite?).

[1] Published by permission of A. Gibb Maitland, Government Geologist.

[2] Bulletins and Annual Reports of the Geological Survey of Western Australia, and Transactions of Aust. Assoc. Adv. Science.

Ixiolite: Wodgina.

Microlite: Greens Well.

Mineral related to Fergusonite: Cooglegong.

Euxenite: Cooglegong.

To this list must now be added tapiolite, which has been discovered at Greens Well and Tabba-Tabba Creek.

The natural compounds of tantalic and niobic acids with iron and manganese are all metatantalates and metaniobates of the general form $(FeTa_2O_6)_n$. On crystallographic grounds they are divided into two groups, the tantalite group which is orthorhombic, and the tapiolite group which is tetragonal and isomorphous with the rutile group.

The chief members of the series are:

Tantalite Group:

Ferrotantalite,	$(FeTa_2O_6)_n$
Manganotantalite,	$(MnTa_2O_6)_n$
Ferrocolumbite,	$(FeNb_2O_6)_n$
Manganocolumbite,	$(MnNb_2O_6)_n$

Tapiolite Group[1]:

Tapiolite,	$(FeTa_2O_6)_m$
Ixiolite,	$(MnTa_2O_6)_m$
Mossite,	$(FeNb_2O_6)_m$
$(MnNb_2O_6)_m$ and $(CaTa_2O_6)_m$, unknown as independent minerals, but found in minor amount in isomorphous mixture with the other members of the group.	
Rutile,	$(TiTi_2O_6)_m$
Cassiterite,	$(SnSn_2O_6)_m$, &c.

To these must be added two important sub-species:

Strüverite,	$4(FeTa_2O_6)_m + (TiTi_2O_6)_m$ to $(FeTa_2O_6)_m + 4(TiTi_2O_6)_m$
Ilmenorutile,	$4(FeNb_2O_6)_m + (TiTi_2O_6)_m$ to $(FeNb_2O_6)_m + 4(TiTi_2O_6)_m$

Of the two localities in the Pilbara goldfield where tapiolite has been found, viz., Tabba-Tabba Creek close to the railway crossing, and Greens Well, the latter is about thirty miles due south of the former. Both centres lie within the same large area of granite, which is intersected by pegmatite veins and greenstone dykes and bosses.

[1] The names and formulae ascribed to these minerals are dealt with fully in a paper on the tapiolite group now in course of preparation.

Tabba-Tabba Creek.

Tabba-Tabba Creek runs almost due north into the Indian Ocean in long. 118° 55′ E. Alluvial tin claims have recently been taken up at two points on it about ten miles apart, the more northerly being known locally as Tabba-Tabba North, the other centre simply as Tabba-Tabba. It is in association with alluvial tin-ore from the former spot that tapiolite has been recognized.

The mineral was separated as follows: In the case of the finer grained ore in fragments up to one centimetre in diameter the mixture was treated in a zinc tray with dilute hydrochloric acid for a few minutes, the acid then washed off with clean water, and the fragments of cassiterite, now coated with bright metallic tin, were picked out and rejected. In the case of larger fragments, small chips were taken off each and treated on zinc with hydrochloric acid. Though many fragments of the tantalum minerals thus selected were either not crystallized, or too imperfectly so for their crystalline system to be determined, a fair number of well-crystallized fragments were obtained, measurements of which left no doubt as to their tetragonal form, whilst their high specific gravity distinguished them from rutile, &c.

At first sight the crystals of tapiolite from this locality would appear to be monoclinic, several having a distinct resemblance in form to orthoclase. Since the form, however, in no wise recalled that of the orthorhombic ferrotantalite series, and in view of the recorded distortions of form already noted in cassiterite,[1] rutile,[2] tapiolite,[3] and strüverite,[4] their true nature was early suspected and subsequently confirmed by angular measurements supported by specific gravity determinations and an analysis. The distorted form and almost invariable twinning caused considerable difficulty in some cases in establishing the correct orientation of the crystals. For this purpose the most useful measurements were found to be:[5]

	°	′		°	′
a^1a^2	= 90	0	a^1r^1	= 33	41
a^1a^3	= 180	0	$a^2(a^4)$	= 65	46
$a^1(a^1)$	= 180	0	s^1s^2	= 57	0

[1] W. G. Woolnough, Proc. R. Soc. N. S. W., 1901, vol. xxxv, p. 332.
[2] W. P. Headden and L. V. Pirsson, Amer. Journ. Sci., 1891, vol. xli, p. 249.
[3] C. H. Warren, Amer. Journ. Sci., 1898, vol. vi, p. 121.
[4] A. Lacroix, Bull. Soc. franç. Min., 1912, vol. xxxv, pp. 187–191.
[5] The faces of the rotated half of the twin are bracketed.

Two other common angles, however, approximated closely to s^1s^2, and were at times the cause of some confusion. These were

$$a^1r^2 = 56°\ 19' \qquad a^1e^1 = 57°\ 7'$$

The recognizable crystals ranged in weight from about one gram to 120 grams, and were with one possible exception unsuited for exact measurement owing to the corroded and often slightly weathered surfaces. The one exception has been reserved for measurement with a theodolite-goniometer, whilst the others have been measured with a contact goniometer.

The axial ratios ($a : c$) recorded for four of the five tantalum-niobium minerals of the tetragonal group are:

	c.	
Tapiolite	0·6464	(Nordenskiöld).
,,	0·6525	(Brögger).
Mossite	0·6438	(Brögger).
Strüverite	0·6456	(Zambonini).
,,	0·6469	(Ungemach).
Ilmenorutile	0·6436	(Eremyeev).

Nordenskiöld's value was used in calculating the theoretical angles, against which the measurements were checked.

The common minerals of the group, viz. rutile, cassiterite, and zircon, have yielded a large number of forms, but, except in the case of ilmenorutile, the already recorded forms for the tantalum and niobium minerals are comparatively few. The complete list is:

Anglo-American notation.	French notation.[1]	Symbol.	Mineral.
a	h^1	100	T, M, S, I.
c	p	001	T, M, I.
m	m	110	T, M, S, I.
Q	h^4	530	S.
r	h^5	320	T, I.
l	h^2	310	I.
x	$h^5/_3$	410	I.
s (p)	$b\frac{1}{2}$	111	T, M, S, I.
ϕ	$b^1/_3\, b^1/_{12}\, h^1/_{10}$	6·9·10	M.

[1] For comparison of Ungemach's and Lacroix's figures with those in the present paper.

μ	$b^4/_9$	998	I.
t	$b\frac{1}{2}\ b^1/_4\ h^1/_3$	313	I.
f	z	323	S, I.
z	$b^1\ b^1/_5\ h^1$	321	I.
ρ	$b^1/_4$	221	I.
e	a^1	101	T, M, S, I.
y	$a^5/_3$	305	M.
v	$a^1/_3$	301	T, M.
w	$a^1/_5$	501	I.

Of these forms e has been recognized as a common twinning-plane.

In this table T stands for tapiolite, M for mossite, S for strüverite, and I for ilmenorutile. The authorities are: for tapiolite, Nordenskiöld, quoted by Dana, and C. H. Warren[1]; for mossite, Brögger, quoted by Dana; for strüverite, Zambonini,[2] Lacroix,[3] and Ungemach[4]; for ilmenorutile, Eremyeev.[5]

Of the above forms the Tabba-Tabba tapiolite has yielded the common forms a, c, s, and e, whilst a further form r is frequently present. This form is known in cassiterite and rutile, and is present in ilmenorutile and Nordenskiöld's skogbölite (since proved to be tapiolite), in which through wrong orientation it was figured as o (211) and p (111). Twins on e are very abundant.

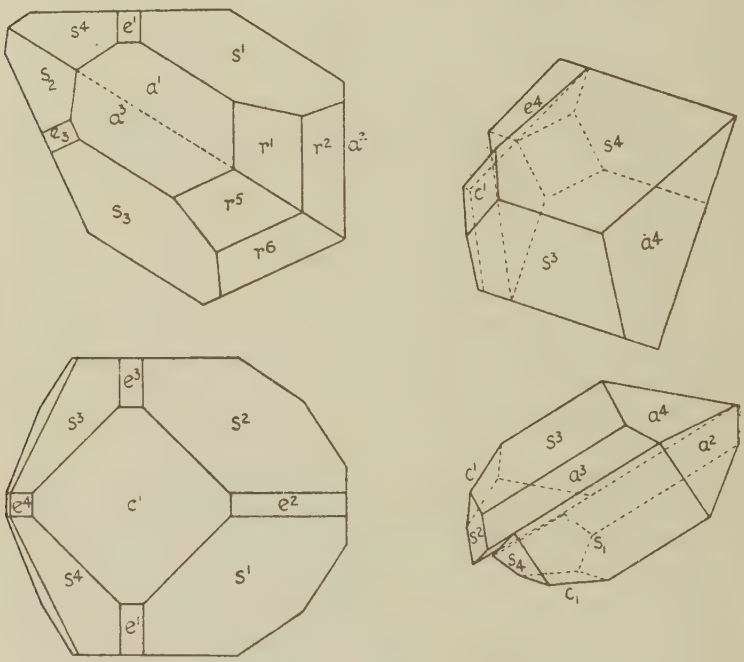
Figs. 1 to 4 illustrate typical crystals from Tabba-Tabba North, which exhibit the characteristic features of twinning on e, elongation parallel to the edge s^1s^2 (or other adjacent pair of unit pyramid-faces), and unequal development of the various faces of the one form.

Crystal I is unique in having a prismatic habit parallel to the vertical axis. The outline of the basal section is somewhat distorted owing to the irregular development of the faces; those present are: a^1, a^2, a^3, r^1, r^2, r^3, r^4, r^5, s_3, s_4, and one small face which is probably e^4, and a second which may be d^2 (058) or (a^4).[6] The angular measurements obtained are given in the table below. This fragmentary detrital crystal weighs 18½ grams, and has a density of 7·69 (compared with water at 4°).

Crystal II, illustrated in orthographic projection in fig. 1, is one of three parallel crystals forming a group which has been but little affected

[1] C. H. Warren, Amer. Journ. Sci., 1898, vol. vi, p. 121.
[2] F. Zambonini, Mineralogical Magazine, 1908, vol. xv, p. 79.
[3] A. Lacroix, Bull. Soc. franç. Min., 1912, vol. xxxv, p. 186.
[4] H. Ungemach, ibid., 1916, vol. xxxix, p. 8.
[5] Quoted by Hintze, Handbuch d. Min., 1907, vol. i, p. 1611.
[6] $a^3d^2 = 68°\ 0'$; $a^3(a^4) = 65°\ 46'$.

by the destructive effects of stream action. It is only slightly fractured, and some quartz is still firmly attached to it in sheltered corners, accompanied by some small scales of mica. The group weighs 27 grams, and has a specific gravity of 7·26 inclusive of the quartz. It was received from Port Hedland, the nearest port to Tabba-Tabba, which is probably, though not certainly, its original locality.



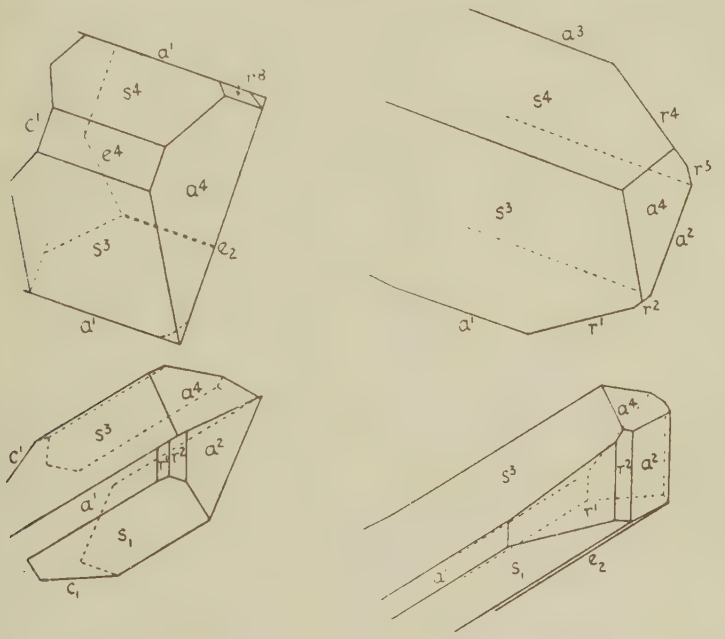
Tapiolite from Tabba-Tabba Creek, Western Australia.

Fig. 1.—Orthographic projections (somewhat idealized) of twinned crystal II from triple group. The original is an almost perfect reflection-twin on e^2 (011).

Fig. 2.—Plan and clinographic projection of twinned crystal III. Steps on a^3 and (a^4) omitted. The left-hand side of the crystal is imperfectly developed in the original. A dislocated twin on e^4 ($0\bar{1}1$).

The crystals are twinned on *e*, and the various faces in the group are more regularly developed than in most cases, whilst the transverse axes of each part of the twin lie almost in the same vertical plane (parallel to 100), which was not the case with most of the twins from this locality. In this instance the twin was an almost perfect reflection-twin over the

face (011). Though rotation about a normal to this plane would bring all the faces into normal crystallographic orientation, it would not yield a perfect crystal, since the outlines on either side of the composition-plane are quite different, there being no prism-faces on the left-hand side of the crystal. The faces have, however, been lettered as for a rotation-twin, as this appeared the method more suited to the other crystals here described.



Tapiolite from Tabba-Tabba Creek, Western Australia.

FIG. 3.—Plan and clinographic projection of twinned crystal IV. A dislocated twin with prism-faces unequally developed.

FIG. 4.—Plan and clinographic projection of twinned crystal V. A dislocated twin with undulating composition surface.

Crystals III and IV (figs. 2 and 3) illustrate the form of twin more commonly developed at Tabba-Tabba. This is still a twin on *e*, but is not a reflection-twin, and though rotation through 180° about a normal will bring all faces into uniform orientation, it will not lead to a perfect crystal. Very noticeable is the dislocation of the centre in the two halves along that one of the horizontal axes which lies in the twinning-plane,

a condition prevailing to a greater or less degree in all the twins from this locality. The various faces of the same form in the prism-zone (100 and 320) are very unequally developed, pointing to a low order of symmetry in this mineral. A study of the figures shows that crystals III and IV may further be looked upon as right- and left-hand reciprocals. In both cases there is an elongation in the direction of the edge s^3s^4.

Crystal III (fig. 2) is large, weighing 79 grams, and has a specific gravity of 7·52. Though not fractured, the left-hand side is poorly developed owing to interference by other minerals of the pegmatite vein during growth. Faces a^2, (a^4) are stepped with small faces r^1 and (r^5) forming the junction; this is not shown in the figure.

Crystal IV (fig. 3) is a smaller, 7 grams, corroded, and imperfectly developed individual with a specific gravity of 7 . 44.

Crystal V (fig. 4) illustrates a somewhat different twin. This resembles the other crystals in its elongation parallel to the edge *ss* and in its twinning on *e*, and in the dislocation of the twinned half. The differences lie in a still further departure from the form of a reflection-twin, the shape of the upper and lower halves of the crystal being markedly different, and in the fact that the composition-surface is no longer a simple plane *e*, but an undulating surface, the faces r^1, r^2, r^3, r^4 rising above the plane *e* drawn through the edge $a^2(a^4)$, and the faces (s^3), (s^4) descending below it. This crystal weighs 4·7 grams, and has a specific gravity of 7·46.

The principal angles measured on these crystals with a contact goniometer are:

Angle.[1]	Calculated.	Crystal I.	Crystal II.	Crystal III.	Crystal IV.	Crystal V.
	° ′	°	°	°	°	°
$a^2(a^4)$	65 46	—	—	66	66	66
$a^2(a^3)$	90 0	—	—	90	90[2]	—
a^1a^2	90 0	90	—	90	90	90
a^1r^1	33 41	34	33½	34	34	—
a^1r^2	56 19	56	—	—	56	56
a^2c^1	90 0	—	90	91	90	—
$(a^4)(e^4)$	57 7	—	—	—	57	—
e^1c^1	32 53	—	33	—	32½	—
a^1s^1	61 30	61½	—	—	61	61
s^1s^2	57 0	57	57	57	57	57

[1] Or corresponding pair of faces.

[2] The angle $a^2(a^1)$.

In order to determine the composition of this mineral, a fractured and slightly weathered crystal was chosen which had been found associated with crystal III, and which had approximately the same density, viz. 7·45. This crystal weighed 35 grams, and about one-third of it was broken off and crushed. The results of the analysis of this portion are:

Tapiolite from Tabba-Tabba North.

	Per cent.		Molecular ratios.	
Ta_2O_5	82·55	...	186	191
Nb_2O_5	1·37	...	5	
TiO_2	0·18	...	2	
SnO_2	0·34	...	2	
Fe_2O_3	0·83	...	5	
FeO	10·69	...	149	207
MnO	1·49	...	21	
CaO	1·96	...	35	
MgO	0·10	...	2	
H_2O (over 105° C.) ...	0·31			
	99·82			

To make sure that the substance weighed as lime was really so,[1] its molecular weight was determined by conversion into sulphate. The result obtained was 56·05, which agrees with that calculated from the 1916 International Atomic Weights Table, viz. 56·07. The figures could not be correlated with any known rare earth sesquioxide, nor was the hydrate precipitated by ammonia. The small magnesia precipitate was tested colorimetrically for manganese, which was found to be absent from it. The analysis was made wholly in vessels of quartz and platinum, except for the preliminary fusion with caustic potash, which was made in a nickel crucible for the estimation of the acid oxides and in a silver crucible for the estimation of the strong bases. The purity of all reagents was proved before use.

The physical characteristics of the Tabba-Tabba tapiolite are as follow: Form, often well-crystallized, usually in twins on (101), and elongated parallel to the edge of adjacent unit pyramid-faces; at other times in rough fragments, water-worn to various degrees. Density, 7·36 to 7·69. Hardness, 6¼. Brittle, no cleavage. Colour on fresh fracture, pure

[1] W. T. Schaller does not accept $CaTa_2O_6$ as isomorphous with $MnTa_2O_6$ and $FeTa_2O_6$. W. T. Schaller, 'The rutile group,' U. S. Geol. Survey, Bull. 509, 1912, pp. 10–13, 19–20.

black; colour of surface, black to dark brown, the brown tints being a sign of a thin surface weathering. Opaque, except in very fine powder (1/25 mm.), which is translucent under the microscope and dichroic, light to very dark brown. Birefringence, strong.

Greens Well (Chingamong).

Some time ago a few small pure black crystals were collected in alluvium at Greens Well (sometimes known as Chingamong), about thirty miles south of Tabba-Tabba. On account of their high specific gravity, 7·84 to 7·91, these were suspected to be a tantalum mineral, and subsequent crystallographic examination proved their identity with tapiolite. The crystals are small, 2·1 to 3·5 grams, and broken, but such faces as are preserved are mostly but little corroded, and have a brilliant lustre, making them suitable for exact measurement, for which

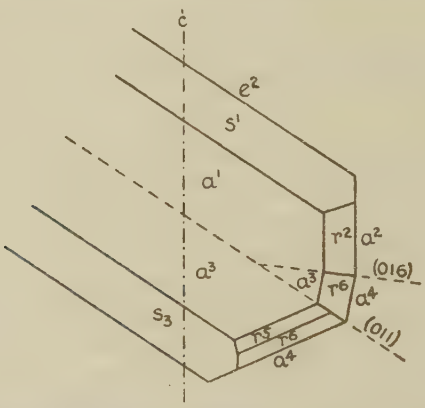


Fig. 5.—Tapiolite from Greens Well, Western Australia. Projection on (100) showing double twinning, viz. on (011) and (016).

purpose they are being carefully preserved. A preliminary measurement of the angle *as* with a two-circle goniometer gave a reading of 61° 19′ as against 61° 30′ calculated from Nordenskiöld's value for *c*, viz. 0·6464.

In one crystal, fig. 5, in addition to the usual twinning on *e* yielding a form similar to that of strüverite from Ampangabe, Madagascar, illustrated by Lacroix's fig. 10, page 190 of the Bulletin de la Société française de Minéralogie for 1912, there is further a small inset which is a twin on (106), previously not known as a face or twinning-plane in this series of minerals. An orthographic projection of this crystal on (100)

is given in fig. 6. Pending final measurement, the faces present appear to be:

Upper half of twin: a^1, a^2, r^2, r^3, s^1, s^2, e^2.
Small inset: a^3, a^4, r^6, r^7.
Lower half of twin: a^3, a^4, a^1 ?, r^5, r^6, r^7, r^8, s_3.

Measurements on this crystal gave the following angular values:

Angle.	Measured.	Calculated Nordenskiöld.	Calculated Brögger.
	° ′	° ′	° ′
$a^2((a^4))$	12 20	12 18	12 24
a^1a^2	90 0	90 0	90 0
ar^1	33 36	33 41	33 41
ar^3	56 39	56 19	56 19
ae	56 48	57 7	56 53½
as	61 19	61 30	61 21

From ae the length of the vertical axis is calculated to be 0·6543, and from as, 0·6535, the mean of which is 0·6539. Nordenskiöld gives 0·6464, and Brögger, 0·65215.

This crystal weighs 2½ grams, and has a specific gravity of 7·839.

A second crystal from the same locality, with a density of 7·907 and weighing 4 grams, is heart-shaped, with a small re-entrant angle of approximately 11°. This appears to be a twin on (301) somewhat resembling the rutile twin shown in fig. 9 of the 6th Edition of Dana's 'System of Mineralogy' (1892). Owing to imperfect development of faces and to fracturing, it is not suited for exact measurement. The calculated re-entrant angle is 11° 12′ (Nordenskiöld's parameter).

A third distorted and fractured crystal appears to exhibit the following faces: a^1, a^2, r^1, r^2, s^1, s_3, s_4. Of these the most prominent are s^1 and s_4, a^1 and r^2 being moderately large, the others quite small. This crystal weighs 2·7 grams, and has a specific gravity of 7·875.

In addition to the unusual habit exhibited by these crystals, interest centres on the density, which for the pure tetragonal compounds has not been definitely settled. Until this is done it is impossible to study in detail the constitution of strüverite and ilmenorutile, and probably nigrine.

The determination of the specific gravity of a heavy mineral by a Jolly or Walker balance is very unsatisfactory, since owing to the small relative loss of weight in water, an error ranging up to 3 in the first place of decimals may occur in the density. With a chemical balance results correct to units in the second place of decimals are obtained without

difficulty, either by suspension, when the mineral fragment weighs not less than 3 or 4 grams, or by pycnometer for somewhat smaller amounts.

Dana quotes 7·8 to 8·0 as the specific gravity of skogbölite (tapiolite) and 7·85 for the 'nearly pure iron tantalate' from Skogböle having the following composition:

Ta_2O_5.	Nb_2O_5.	FeO.	MnO.	CaO.	CuO.	SnO_2.	Total.
84·44	?	13·41	0·96	0·15	0·14	1·26	100·36.

The figures 7·8 to 8·0 are evidently to be considered approximate and liable to an error of anything up to 0·3.

For the original tapiolite[1] from Sukula, Tammela, Finland, Nordenskiöld found a density of 7·36, and Rammelsberg 7·496, the mineral having the composition:

Ta_2O_5.	Nb_2O_5.	FeO.	MnO.	SnO_2.	Total.
73·91	11·22	14·47	0 ·81	0·48	100·89.

Warren[2] gives 7·66 to 7·87 for tapiolite from Topsham, Maine. Prior[3] in 1913, after quoting the above analyses, writes: 'The density of these tetragonal metaniobates and tantalates, however, appears to be greater than that of the orthorhombic minerals of similar composition.'

In dealing with strüverite, D'Achiardi[4] assumes the density of pure mossite ($FeNb_2O_6$) to be 6·45, a value based on the assumption that Brögger's mossite from Moss was pure $FeNb_2O_6$, which is very far from the truth. Crook and Johnstone[5] in discussing the constitution of strüverite from Perak assume 7·3 to be the 'specific gravity of a typical tapiolite, i. e. one containing only a few per cent. of niobic oxide'.

Schaller,[6] from the value 7·85 for tapiolite and 6·45 for type mossite with equal molecules of tantalate and niobate, calculates 5·05 to be the density of pure $FeNb_2O_6$, a value with which, however, he is not too well satisfied, and which he queries in his tabulation. From the same data the present author calculates a density of 5·14 for $FeNb_2O_6$, using the formula

$$\text{Density} = \frac{\text{Molecular weight}}{\text{Molecular volume}} = \frac{338{\cdot}84}{65{\cdot}9},$$

where 65·9 is the mean of the molecular volumes calculated from his data for tapiolite and 1 : 1 mossite, viz. 65·6 and 66·2. Schaller assumes

[1] Dana's 'System of Mineralogy', 6th edit., 1892, p. 738.
[2] C. H. Warren, loc. cit.
[3] G. T. Prior, Doelter's Handbuch der Mineralchemie, 1913, vol. iii, p. 264.
[4] G. D'Achiardi, ibid., 1913, vol. iii, p. 27.
[5] T. Crook and S. J. Johnstone, Mineralogical Magazine, 1912, vol. xvi, p. 231.
[6] W. T. Schaller, U. S. Geol. Survey, Bull. 509, 1912, p. 11.

from very limited data a progressive increase in molecular volume in passing from tapiolite to mossite, the volume being taken as a linear function of the percentage composition of the mineral. His molecular volume for pure mossite, however, on this theory becomes 67·1, which is doubtful in view of the free crystalline intergrowth of $FeNb_2O_6$ with $TiTi_2O_6$, the latter having a molecular volume of at most 60·0, and is unsupported by density determinations of actual minerals. If anything, one would expect the molecular volume of $FeNb_2O_6$ to be less than that of $FeTa_2O_6$ and nearer that of $TiTi_2O_6$.

Assuming that the tetragonal isomorphous series consisting of the metaniobates and metatantalates of iron, manganese, and calcium have an identical molecular volume, the highest specific gravity will be found in the pure compound having the highest molecular weight, viz. $FeTa_2O_6$. The highest specific gravity recorded for any mineral of this group is that now given for a crystal from Greens Well, viz. 7·907, and in view of the somewhat lower densities obtained for but slightly impure iron tantalate from other localities, the error in assuming 7·90 to be the density of pure tapiolite ($FeTa_2O_6$) must be extremely small. From this figure the molecular volume of the various members of the series is calculated to be 65·2 and the densities of the various pure minerals as follow:

$FeTa_2O_6$ (Tapiolite)	7·90	$FeNb_2O_6$ (Mossite)	5·20
$MnTa_2O_6$ (Ixiolite)	7·88	$MnNb_2O_6$	5·18
$CaTa_2O_6$ [1]	7·65	$CaNb_2O_6$	4·95

Given these values, the density may be used as a check upon the analytical figures obtained, particularly upon those for Ta_2O_5 and Nb_2O_5, by means of the known hyperbolic (not linear as so often assumed in mineralogical literature) relationship between the percentage composition of a mixture and its density, viz.

$$P_h = \frac{100\,D_h(D_m - D_l)}{D_m(D_h - D_l)},$$

[1] W. T. Schaller, loc. cit., omits these proved calcium isomorphs from his list and fails to take the lime and magnesia into consideration in discussing my analysis of Wodgina ixiolite. On the other hand, he includes $FeTiO_3$, whose only claim to existence as a tetragonal compound, except the very doubtful 'iserite', are some analyses of rutile and nigrine in which neither Nb_2O_5 nor Ta_2O_5 nor V_2O_5 have been looked for, though all three are probably present, and lastly analyses of ilmenorutile and strüverite in which the relative figures for Ta_2O_5, Nb_2O_5, and TiO_2 are not absolutely above suspicion, and of which in any case a different interpretation, not involving $FeTiO_3$, is possible. The present author contends on theoretical grounds that $FeTiO_3$ cannot be isomorphous with the series of compounds here discussed.

where P_h is the percentage present of the compound with higher density,

D_h the density of the heavier compound,

D_l the density of the lighter compound,

D_m the experimentally determined density of the mineral.

Having determined the densities of pure tapiolite and mossite, the relationship which strüverite and ilmenorutile bear to rutile, on the one hand, and to tapiolite and mossite, on the other hand, may be graphically

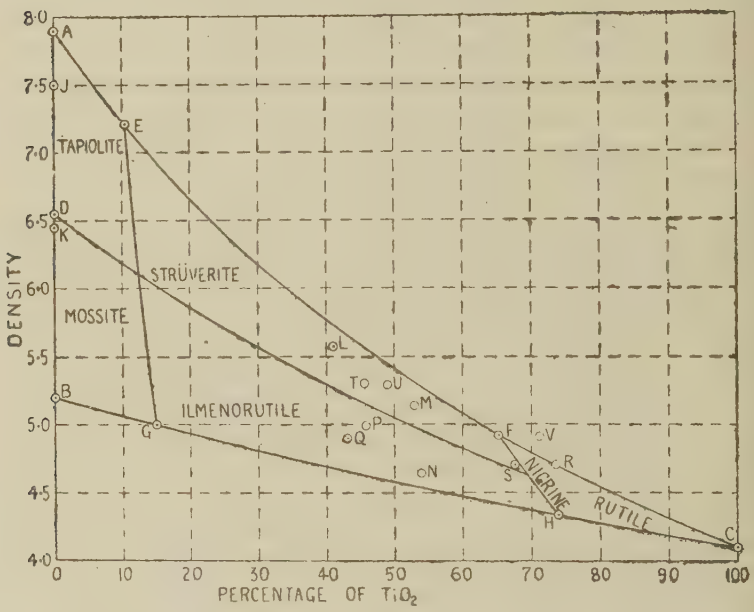


Fig. 6.—Graph showing relationship between tapiolite, mossite, rutile, strüverite, ilmenorutile, and nigrine.

A. Pure $FeTa_2O_6$, Tapiolite, Greens Well. D, 7·90.
B. Pure $FeNb_2O_6$. D, 5·20.
C. Pure $TiTi_2O_6$. D, 4·10.
D. $FeTa_2O_6 + FeNb_2O_6$. D, 6·55.
E. $4\,FeTa_2O_6 + TiTi_2O_6$.
F. $FeTa_2O_6 + 4\,TiTi_2O_6$.
G. $4\,FeNb_2O_6 + TiTi_2O_6$.
H. $FeNb_2O_6 + 4\,TiTi_2O_6$.
J. Type Tapiolite, Tammela.
K. Type Mossite, Moss.
L. Type Strüverite, Craveggia.
M. Type Ilmenorutile (Strüverite ?), Miask.
N. Typical Ilmenorutile, Iveland.
P. Ilmenorutile, Lake Monger, W. A.
Q. Ilmenorutile, Melville, W. A.
R. Ilmenorutile ?, Evje.
S. Ilmenorutile (Strüverite ?), Tvedestrand.
T. Strüverite, Perak.
U. Strüverite, Black Hills.
V. Strüverite ?, Ampangabe.

illustrated as is done in fig. 6. In this figure the equation for the curve AEFC, calculated from the foregoing general formula, is:

$$D = 852{\cdot}4 \div (107{\cdot}9 + R),$$

for the curve BGHC $D = 1938{\cdot}2 \div (372{\cdot}7 + R)$,

and for the curve DSC $D = 1095{\cdot}8 \div (167{\cdot}3 + R)$,

D in each case being the density of the mixed crystal, R the percentage by weight of rutile (TiO_2) present.

The ratio 4 : 1 taken as the limiting point between tapiolite and strüverite, &c., may appear to be arbitrary, as to some extent it undoubtedly is, but was not chosen without consideration, though other adjacent ratios such as 5 : 1 or 3 : 1 might be substituted.

The equivocal position of the type ilmenorutile from Miask on Prior's data[1] as to density and percentage of titanium oxide should be noted. The mineral from Iveland is unquestionably typical, as also apparently minerals found at Melville and Lake Monger in the Yalgoo goldfield of Western Australia, of which only preliminary data are at present available.

Perth, W. A.
September 11, 1916.

[1] In the discussion following the reading of this paper, Dr. G. T. Prior remarked that since the publication of his own results (this Magazine, 1908, vol. xv, p. 80) he had realized that, with the small amounts of material at his disposal, the Marignac method for the separation of tantalic and niobic acids gave in all probability results much too low for tantalic acid. Until accurate methods or the separation of tantalic and niobic acids have been devised, the position in the strüverite-ilmenorutile series of the minerals he then analysed is best given by the density and percentage of titanium dioxide, the general accuracy of the data for which there is no reason to doubt.

The use of the orthographic projection in crystallography.

By Harold Hilton, M.A., D.Sc.,

Professor of Mathematics in Bedford College (University of London).

[Read January 16, 1917.]

§ 1. THE geometrical representation of the faces and edges of a crystal is obtained (i) by drawing lines through a fixed point O perpendicular to each crystal-face meeting a fixed sphere with centre O in a point (*face-pole*) representing that face, (ii) by drawing lines through O parallel to each crystal-edge meeting the sphere in a point (*edge-pole*) representing that edge. This representation is inconvenient as being in three dimensions, and therefore it is customary to map the sphere on a plane. This is usually done by means of the stereographic or gnomonic projection. But the actual drawing of the crystal is made on a different projection, namely the orthographic (or orthogonal). There are therefore many advantages in mapping the sphere on the same projection; any point p of the sphere being mapped on a fixed plane Π through O by the foot P of the perpendicular pP from p on the plane Π. The map gives the appearance of the sphere as seen by an eye at a considerable distance situated in the normal through O to Π. We shall call the intersection of Π with the sphere the *fundamental circle* of the projection.[1]

The great advantage of this method consists in the fact that the line joining O to the orthographic projection of an edge-pole is parallel to the corresponding edge in the final drawing of the crystal. The finding of the directions of these edges is a necessary preliminary to the execution of the drawing.

The main disadvantages of the orthographic projection are (i) that it is not so easy to draw as the stereographic or gnomonic projection, for the projection of a great circle is not a circle or straight line but an ellipse

[1] We denote the projections of $p, q, \ldots$ by $P, Q, \ldots$ throughout. If P lies on the fundamental circle, p coincides with P.

with a diameter of the fundamental circle as major axis, and (ii) that there is undue compression near the circumference of the fundamental circle. The objection (ii) is less important than appears at first sight, for the resulting error in plotting the position of an edge-pole makes but little difference to the final drawing of the crystal. We shall consider objection (i) later on in more detail.

§ 2. The easiest way to draw the projection is by means of the *orthographic net*. This is an orthographic projection of the great circles whose planes pass through a diameter λ of the sphere (meridians) and of the small circles having λ as axis (lines of latitude) on to a plane through λ. The projections of the meridians are ellipses with λ as a common major axis. Their minor axes lie along a line μ perpendicular to λ. The projections of the lines of latitude are straight lines perpendicular to λ.

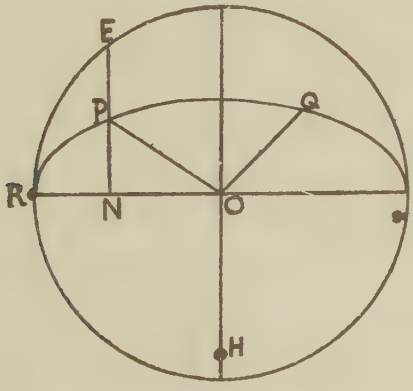


Fig. 1.

The use of the net is exactly similar to that of the well-known gnomonic and stereographic nets; and by their aid any one of the three projections is drawn with equal ease.

The projection is drawn on tracing-paper, the centre O of the drawing being always over the centre of the net.

For instance, suppose we have the projections P, Q of two face-poles p, q (fig. 1). Then to get the projection H of the pole h of the edge in which the two faces meet, turn the diagram about O until P and Q lie on the same meridian of the net, and measure off along the line μ an angular distance of 90° from this meridian. Thus H is obtained.

Gnomonic, stereographic, and orthographic nets were drawn by F. E. Wright and appended to his work on 'The methods of petrographic-

microscopic research' (Washington, The Carnegie Institution, 1911). He does not apply these nets to crystal-measurement. Further details as to the use of nets, with references, will be found in papers by the author and Dr. Hutchinson in volumes xiv and xv respectively of this Magazine.

The cross-ratio of four co-zonal faces with poles p, q, r, s is equal to the cross-ratio of the pencil $O(PQRS)$, where O is the centre of the projection. It may be obtained graphically, when the projection has been drawn, by measuring the intercepts made by the rays of this pencil on a line parallel to any one of them.

§ 3. Suppose now that we have an orthographic projection on the plane Π of the face- and edge-poles: and that we require the projection on Π when the sphere and the crystal, which is supposed rigidly attached to the sphere, is rotated about an axis through O.[1] There will be no loss of generality in supposing the rotation to take place about an axis in Π. For any rotation may be shown to be equivalent to a rotation about an axis in Π followed by a rotation about the normal to Π; and this second rotation does not alter the drawing of the crystal. Suppose then the rotation to be through an angle θ about an axis in Π. We place this axis along the diameter λ of the net and move each pole of the diagram along its line of latitude (perpendicular to λ) through an angular distance θ, as given by the meridians of the net. We have then the new projection required.

It is important to notice that, if we draw the pictures of the crystal in the two positions, the line joining the two positions of a given vertex of the crystal is perpendicular to the axis of rotation λ. Hence, if one drawing has been obtained, the other is immediately derived. For we know the directions of the edges of the crystal in the other drawing, and lines perpendicular to λ along which its vertices lie. For the first drawing we may with advantage choose Π perpendicular to an axis of symmetry, or perpendicular to some important zone of the crystal, as recommended also by other authors.

§ 4. We now show how to draw the 'axial cross' of a crystal. Let the crystallographic axes Oa, Ob, Oc meet the sphere in a, b, c. The projections A, B, C of a, b, c are at once drawn by the aid of the net in the case in which Ob and Oc lie in the plane Π (fig. 2). Let OL be the line in Π perpendicular to OC. The axial cross is now usually drawn by rotating the trihedron Oa, Ob, Oc about OC through an angle θ and then about OL through an angle ϕ. These rotations are equivalent to a rotation through an angle ψ about a line OK in Π followed by a rotation through

[1] It comes to the same, if we suppose the sphere kept fixed and Π altered.

an angle ϵ about the normal to Π, where $\tan KOC = \tan\phi \,.\, \operatorname{cosec}\theta$, $\tan\frac{1}{2}\epsilon = \tan\frac{1}{2}\theta \,.\, \tan\frac{1}{2}\phi$, and $\cos\frac{1}{2}\psi \,.\, \cos\frac{1}{2}\epsilon = \cos\frac{1}{2}\theta \,.\, \cos\frac{1}{2}\phi$.

In this all rotations are in the clockwise direction to an observer looking along the axis of rotation towards O.[1]

The final projection of the ends of the crystallographic axes is now found by making OK coincide with the diameter λ of the net, and moving A, B, C perpendicular to λ through an angle ψ as given by the meridians of the net. The projection of the crystallographic axes is found by joining O to the new positions of A, B, C. The 'axial cross' is obtained by multiplying OA, OB, OC by the axial ratios.

In fig. 2 we show the case in which the angles between the crystallographic axes are 100°, 108°, 94°. The tail and point of the arrows are the original and final positions of A, B, C respectively.

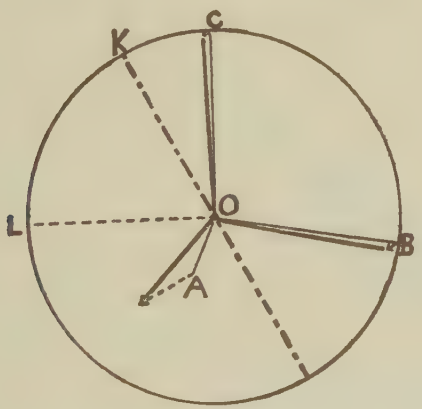


Fig. 2.

§ 5. If an orthographic net is not to hand, we may replace it by the following device, which also avoids the use of tracing-paper. We shall suppose the fundamental circle to be of 10 centimetres radius. On paper ruled in millimetre squares draw $XY = 10$ cm., and XZ perpendicular to it, along lines on the squared paper. Graduate XY as in fig. 3; the division representing an angle θ being $10 \,.\, \sin\theta$ centimetres from X. Join the division marks to Z.

Suppose the crystal to be measured on a two-circle goniometer. Take the plane Π parallel to the central face (perpendicular to the principal

[1] e.g., if $\theta = \tan^{-1}\frac{1}{3} = 18°\ 26'$, $\phi = \tan^{-1}\frac{1}{6} = 9°\ 28'$, then $COK = 27°\ 48'$, $\epsilon = 1°\ 32'$, $\psi = 20°\ 38'$. These values are taken in fig. 2.

zone) of the goniometric readings. If p is the pole of any face at an angular distance ρ from the central face, the distance OP in the projection is $10 . \sin \rho$ centimetres. Hence the projection of the face-poles is at once drawn.

Now suppose we have two face-poles p, q, and that h is the edge-pole of the edge in which the two faces with poles p, q meet. We know P, Q, and require to find H (fig. 1).

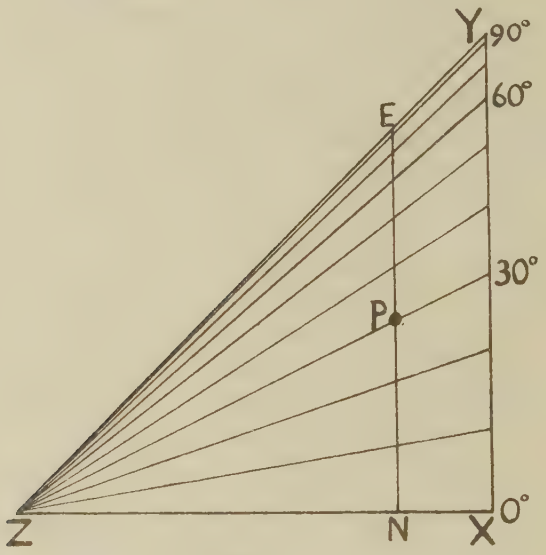


Fig. 3.

Suppose that the great circle pq meets the fundamental circle in r (coinciding with R). If the position of R has not been already obtained, we may calculate this position from the formula

$$\tan \sigma . \sin (op - oq) = \tan \tau . \sin (op + oq),^1$$

where $POR = \sigma - \tau$, $QOR = \sigma + \tau$; so that $\tau = \frac{1}{2} POQ$. We know τ, op, oq from the goniometric readings. The position of H is at once obtainable, if we know the angle θ between the great circles pqr and or. It may be calculated from

$$\tan \theta = \tan op . \sin (\sigma - \tau),$$

or obtained graphically as follows. Place a millimetre ruler along EPN in fig. 1 perpendicular to OE. Place the line EPN in fig. 3 with E on

[1] o is the point on the sphere whose projection is O, so that oO is perpendicular to Π.

ZY, N on ZX, and EN perpendicular to ZX. The value of θ is that given at the right-hand end of the line ZP. For the ratio PN/EN is the same for all points p in the zone qr.

Of course θ may be at once read off from the ruler and the squared paper of fig. 3 without actually drawing EN in either fig. 1 or 3. In fact, it is not necessary to have the two figures on the same scale. I have found it convenient to draw fig. 3 on tenth-inch paper with $XY = 10$ inches. Such a diagram may be drawn graduated to every other degree in half an hour or less. A strip of millimetre squared paper serves excellently for the ruler applied to the projection in fig. 1.

Suppose now we have the projection P of any point p on the sphere (fig. 1), and require the new position of P after the sphere has been rotated about any line of Π (say OR) through a known angle ϵ. Place the line EPN in fig. 3 as just described. Move P along the line EN perpendicular to XZ through an angle ϵ as given by the lines through Z. This gives the new position of P, which can be now inserted in fig. 1. As before, we do not actually draw the line EPN, but read off the new position of P immediately on the ruler and squared paper of fig. 3.

To obtain the 'axial cross' we require the positions of A, B, C in fig. 2. We know the angles between the crystallographic axes Oa, Ob, Oc. Hence B and C are at once given. To get A, we note that, since the angle cOa is known, A lies on a known straight line perpendicular to OC. Similarly A lies on a known straight line perpendicular to OB, and thence A is obtained. The new positions of A, B, C after rotating about OK are obtained by the process just described.

§ 6. We illustrate our discussion by showing the drawing of a simple orthorhombic crystal. The observed goniometric readings on the two-circle goniometer are:

face	b	m	m_1	r	r_1
ϕ (longitude)	0°	0°	180°	39°	141°
ρ (distance from central face)	90	53	53	90	90

and the faces parallel to these also exist. We shall denote the projections of the edge-poles by numbers, thus $bmm_1 = 1$, $brr_1 = 2$, $mr = 3$, $mr_1 = 4$, $m_1r = 5$, $m_1r_1 = 6$.

In fig. 4 (i) we show the orthographic projection of the face-poles on Π when the central face (for which $\rho = 0$) is parallel to Π; and the projection of the edge-poles when the central face is parallel to Π and after the crystal has been rotated through 20° about the line λ. The tail of each arrow is the projection of an edge-pole before the rotation, and the

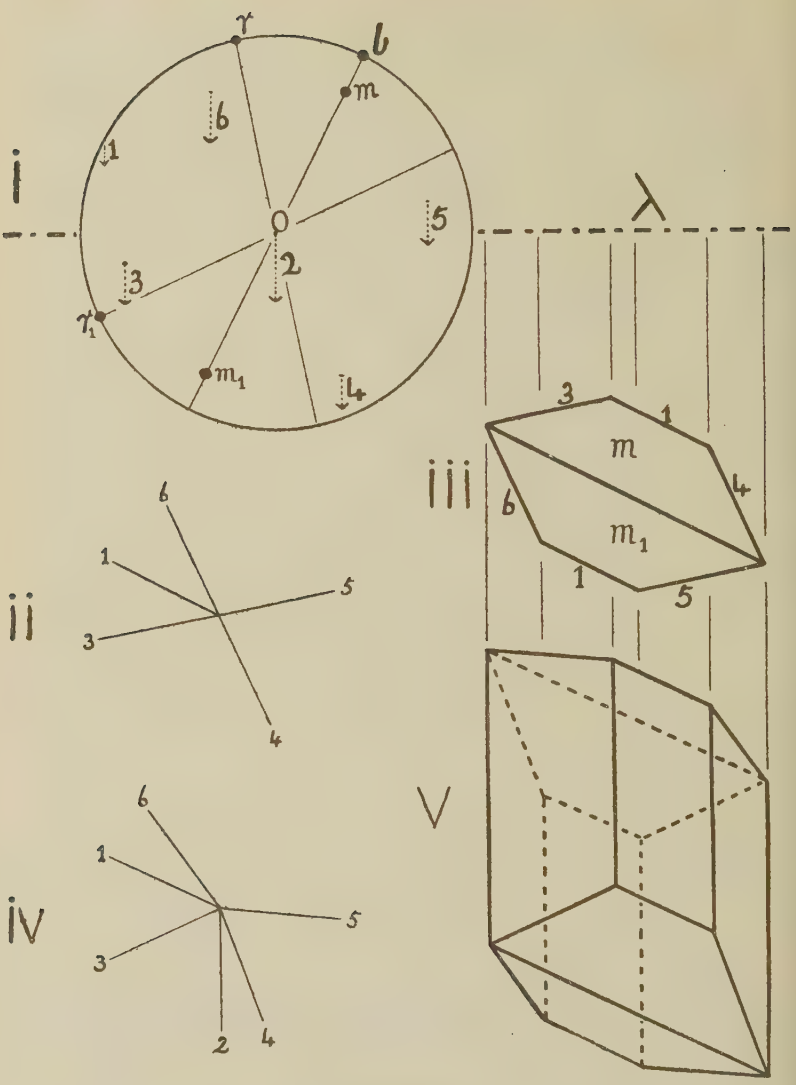


Fig. 4.

point of the arrow the projection after rotation. Of course each arrow is perpendicular to λ. In (ii) are shown the directions of the lines joining O to the projections of the edge-poles before rotation (the tails of the arrows). In (iii) we show the corresponding picture of the crystal. We note that

the edges in (iii) are parallel to the lines in (ii); and then symmetry and a knowledge of the crystal's habit enable us to complete the drawing (iii). In (iv) are shown the directions of the lines joining O to the edge-poles after rotation (the points of the arrows). In (v) we show the corresponding picture of the crystal. The part of the crystal shown in (iii) is at the bottom of (v). We note that the edges in (v) are parallel to the lines in (iv), and that the lines joining corresponding vertices of (iii) and (v) are perpendicular to the line λ. This enables us to complete the drawing (v); the ratio of the lengths of edges 1 and 2 being given by the crystal's habit.

In conclusion I have to thank Mr. T. V. Barker and Miss M. W. Porter for kind assistance which has been of the greatest value in writing this paper.

The use of a slit in determining refractive indices with the microscope.

By John William Evans, LL.B., D.Sc., F.G.S.,

Lecturer in Petrology, Imperial College of Science and Technology, and Birkbeck College.

[Read March 21, 1916.]

CERTAIN optical properties of crystals, and more particularly the refractive index, may be determined either in the directions-image, often referred to as the 'image in convergent light', or in the ordinary object-image in which the object itself is seen. In the former case, in which the index of refraction is usually determined by means of the critical angle of total-reflection, every point in the image corresponds to a single direction of propagation of the wave-front through the crystal-structure and to the two corresponding directions of vibration. One of these can, however, be eliminated by the insertion of a nicol in an approximate position, and thus all ambiguity in the determination of the refractive index is removed.

In the object-image, however, the wave-fronts of the light by which any point is illuminated have traversed the crystal-structure in an infinite number of different directions, and to each of these correspond two directions of vibration, so that there is no definite refractive index which can be determined and only approximate results can be obtained whatever the method employed.

This difficulty may be overcome to a considerable extent by placing a diaphragm with a minute aperture in a position on the microscope axis where a directions-image is formed, or in a focus conjugate to such a position, so that the image of the aperture is seen in focus simultaneously with the directions-image, thus allowing only a small well-defined portion of the latter to be visible or to be illuminated.

By moving the diaphragm laterally, that is to say, at right angles to the axis of the microscope, any point of the directions-image may be rendered visible or illuminated to the exclusion of the rest, so that the

light which passes is limited to that which has traversed the crystal-structure in what is practically one direction only, and with the help of a nicol it may be restricted to that vibrating in one only of the two corresponding directions of vibration. Then by an alteration of the optical system between the diaphragm and the observer, an object-image may be formed and observed, which is illuminated only by this special light.

The simplest method of applying these principles is to insert the diaphragm below the stage in the position in which the iris-diaphragm is usually placed, so that when the Bertrand or Beck lens is inserted or the eyepiece removed it is seen in focus in the directions-image. After the diaphragm has been adjusted as desired, the Bertrand or Beck lens is removed or the eyepiece replaced, and the object-image is seen illuminated only by the vibrations which it is desired to investigate.

If the Bertrand lens be employed to form a directions-image in the focus of the eyepiece, the diaphragm may be placed in that position, and the object-image, formed above the eyepiece, may then be observed with a suitable lens. This image is, however, in the ordinary microscope too high above the eyepiece to be seen with a fixed lens such as the Beck lens without an extra tube, and it is small and ill-defined.[1]

The chief objection to these methods of isolating a particular direction of vibration is the great loss of light which they involve, causing the illumination to be comparatively feeble even with a powerful source of light.

Where, however, a thin section is cut at right angles to a plane of optical symmetry or, what comes to the same thing, a grain is so orientated that a plane of optical symmetry is at right angles to the microscope stage, the direction of vibration at right angles to the plane of optical symmetry may be isolated by means of a diaphragm with a fine slit instead of a small perforation. The slit may be adjustable in the same manner as that of a spectroscope, or the diaphragm may be formed by a metal slide with slits of different widths, which can be used as desired.

The slit is placed in a position of parallelism with the plane of optical symmetry, with the result that all the paths of the light which passes it and illuminates the portion of the object in the axis of the microscope are approximately in that plane. It must therefore, whatever path it follows, have one of its directions of vibration practically normal to the plane in question, and the other in the plane and at right angles to its path. If

[1] J. W. Evans, 'The isolation of the directions-image of small objects', Mineralogical Magazine, 1916, this vol., p. 45.

now a Nicol's prism be inserted in the microscope in such a position that the vibrations of the light which traverses it are at right angles to the plane of optical symmetry, the vibrations in that plane will be eliminated, and the image will be illuminated only by vibrations at right angles to it, which have, of course, all the same refractive index, so that definite results will be obtained.

If the section is at right angles to two planes of optical symmetry, or, what comes to the same thing, if two such planes are parallel to the axis of the microscope, each may in turn be placed parallel to the slit, and thus two indices of refraction may be determined. These will be two out of the three principal indices of refraction, that is to say, those of the three lines or axes of optical symmetry.

In the case of uniaxial crystals, the index of refraction of the ordinary or basal vibrations may be observed in any section, while in a section parallel to the axis of optical symmetry, those of both the ordinary and the extraordinary axial vibrations may be determined.

These methods are applicable to the Chaulnes procedure for determining the refractive index, and they eliminate the bifocal effects described by Sorby.[1] If they are employed with the Schröder van der Kolk method, the finger or other screen must be introduced along the direction of the length of the slit.

If the slit is employed in the Beck method, it must be parallel to the boundary along which the effects are to be obtained. The result is that it is only occasionally that the principles described above can be applied. The slit has, however, in this case another important recommendation. When parallel to the boundary of the minerals to be compared, it gives as definite results as a circular aperture with a diameter equal to its width, and at the same time the field is much better illuminated.

Dr. Tutton pointed out at the reading of the paper that the slit could also be employed to obtain monochromatic light for microscope studies of crystals, if the spectrum from a prism were thrown upon it in such a manner that the individual colours were parallel to the slit and the length of the spectrum at right angles to it.

[1] H. C. Sorby, Mineralogical Magazine, 1877, vol. i, p. 97; 1909, vol. xv, p. 189.

Magnesian Tourmaline from Renfrew, Ontario.

By E. L. Bruce, M.A., B.Sc., Ph.D.,
Junior Geologist, Geological Survey of Canada.

[Read June 20, 1916.]

THE specimens of the mineral examined were obtained from a limestone quarry near the town of Renfrew. The tourmaline occurs near the contact of grey granite-gneiss and crystalline limestone of the Grenville series. The gneiss is intrusive into the limestone, and contact effects are observable both in the intrusive and in the intruded rock. The gneiss consists of quartz, plagioclase, microcline, and a green pyroxene. The limestone is composed (almost entirely) of calcite, but contains some graphite. The secondary minerals occurring in both limestone and gneiss are, besides the tourmaline, pyrrhotite, titanite, and muscovite.

The tourmaline is reddish-brown in colour, with a resinous lustre, and in the hand-specimens had previously been mistaken for garnet. It occurs as grains and as small button-shaped crystals, one of which was measured. This shows in the prismatic zone the trigonal prism m $(10\bar{1}0)$ and the hexagonal prism a $(11\bar{2}0)$. At the antilogous pole are the basal plane c (0001), the ditrigonal pyramid u $(32\bar{5}1)$, and three trigonal pyramids—the unit pyramid r $(10\bar{1}1)$, a steeper pyramid d $(50\bar{5}2)$ truncating the edge between r and m, and o $(02\bar{2}1)$ replacing the corner of the unit form. At the analogous pole only the complementary unit-pyramid r_1 $(\bar{1}01\bar{1})$ appears.

Graphite occurs in the tourmaline very plentifully, and so makes chemical analysis and physical examination somewhat uncertain. However, a small piece was obtained for specific gravity determination which seemed to be free from foreign material. Owing to the small size of the fragment, the heavy solution method (with mercuric potassium iodide) was used. The mean of the determinations gave a result of 3·07.

In polarized light the tourmaline is distinctly dichroic, changing from colourless to light-brown, but owing to lack of well-crystallized specimens the relation of the dichroism to the orientation of the crystals could not be determined. Basal sections give a good uniaxial interference-figure,

and the optical sign is negative. An attempt to determine the refractive indices by means of a prism of the mineral was unsuccessful, owing to its lack of transparency.

To obtain material for a chemical analysis, the rock was coarsely crushed and the tourmaline separated under a lens. Pieces showing graphite were rejected, and most of the calcite was also separated in this way. After this fairly pure substance was obtained it was crushed more finely and leached for some time with hot, dilute acid, thoroughly washed, and dried. It was then crushed still more finely and dried at 110° C. The analyses were made in duplicate. No trace of manganese was found, and the spectroscope failed to show any lithium line. The value obtained for ferrous iron is probably too low, due to the difficulty of decomposing the mineral; and thus the ferric iron, if, indeed, any is present, acquires a correspondingly high value.[1] The water content was determined by the direct method; it is rather low as compared with published analyses.

The results of the analyses are given below in column I; in II are the corresponding molecular ratios, and in III the hydrogen equivalents of the bases. Column IV gives for comparison an analysis of magnesian tourmaline from Hamburg, Sussex Co., New Jersey, made by R. B. Riggs in 1888, as quoted in Dana's 'System of Mineralogy' (Analysis 55, p. 555):

	I.	II.	III.	IV.
SiO_2	35·29	0·588	—	35·25
B_2O_3	10·56	0·151	—	10·45
Al_2O_3	28·93	0·283	1·698	28·49
Fe_2O_3	2·35	0·015	0·090	—
FeO	0·70	0·010	0·020	0·86
TiO_2	0·025	0·0003	—	0·65
CaO	5·49	0·098	0·196	5·09
MgO	14·53	0·360	0·720	14·58
K_2O	0·22	0·003	0·006	0·18
Na_2O	1·72	0·030	0·060	0·94
F	0·84	0·040	—	0·78
H_2O	0·70	0·040	0·080	3·10
	101·355		2·870	100·37
O = F	0·355	...		0·33
	101·00	...	...	100·04
Sp. gr.	3·07			

[1] The total iron reckoned as ferrous oxide corresponds with FeO 2·81 per cent.

The molecular proportions of the acid from which tourmaline is derived would thus be:

	H	SiO_2	B_2O_3	Total Oxygen.
	2·870	0·588	0·151	3·086
or	19·524	4	1·027	20·993
or nearly	20	4	1	21

This agrees with the general formula for tourmaline deduced by Penfield and Foote,[1] namely $H_{20}B_2Si_4O_{21}$ or $H_{18}(BOH)_2Si_4O_{19}$, in which the hydrogen is for the most part substituted by monovalent, divalent, and trivalent basic elements. It is probable, as argued by Penfield and Foote from the limits between which the content of aluminum varies, that part of the aluminum acts as an acid-forming element and the acid of tourmaline is an alumino-borosilicic acid rather than a borosilicic acid.

[1] S. L. Penfield and H. W. Foote, 'On the chemical composition of tourmaline', Amer. Journ. Sci., 1899, ser. 4, vol. vii, pp. 97–125.

OBITUARIES.

Joseph Henry Collins (1841–1916).—Joseph Henry Collins, although of west country parentage, was born in London on March 16, 1841, and his early life, with the exception of a few years in Derbyshire, was spent in London, where, in May, 1867, he won one of the Royal Exhibitions at the Royal School of Mines in Jermyn Street, the privileges of which, however, owing to some official misunderstanding, he never enjoyed.

In April, 1868, Mr. Collins's connexion with Cornwall began by his appointment as Lecturer and Assistant Secretary to the Miners' Association of Cornwall and Devon in succession to the late Dr. (afterwards Sir Clement) Le Neve Foster. In 1870 he resigned the Lectureship of the Miners' Association (retaining, however, the Secretaryship) in order to become Secretary of the Royal Cornwall Polytechnic Society. During the next ten years his literary activities became very prominent, for in addition to publishing in 1871 his 'Handbook to the Mineralogy of Cornwall and Devon', during the years 1872 to 1878 he brought out in rapid succession a series of elementary students' handbooks on mineralogy and the principles of mining, and in the latter year his 'Hensbarrow Granite District'. In 1873 Mr. Collins was appointed Public Analyst to the County of Cornwall, and to most of its boroughs, and about 1874 he began to practise as a mining engineer, directing in that capacity the operations of several mining ventures (including the Perran iron mines), as well as china-clay works. A considerable part of his scanty leisure was devoted to studying the geology of the county, particularly its stratigraphy, and he was the first to demonstrate that the area covered by Lower Silurian strata is much greater than had been previously supposed, and that a large part of the strata in west Cornwall previously supposed to be of Devonian age is in reality much older. The results of his geological studies are contained chiefly in a series of papers published in the Transactions of the local scientific societies, particularly the Royal Geological Society of Cornwall and the Royal Institution of Cornwall.

Early in 1881 Mr. Collins left Cornwall in order to take up a position as chief chemist and metallurgist to the Rio Tinto Company, but his health suffered so much after three years' residence in Spain that he was

obliged to return to England in 1884 and settle in London, where he practised as a mining engineer in partnership with two of his sons, who, as time went on, gradually undertook most of the foreign business, leaving him free to devote himself to work in London as a consulting engineer and mining director. In 1904 he left London to take up residence in Cornwall for the second time, and again to devote himself to his favourite study of Cornish mining geology, upon which subject he read a number of papers before the local societies already mentioned, and in 1912 brought out his 'Observations on the West of England Mining Region', which is already a classic. He had other works in preparation, but a sharp attack of gastro-enteritis, resulting from a chill, put an end to his activities on April 12, 1916.

Mr. J. H. Collins was practically the founder of the Mineralogical Society. During the winter of 1875 he corresponded with a number of gentlemen interested in mineralogy, including Sorby, Heddle, Church, Marshall Hall, Le Neve Foster, Readwin, Trechmann, and others,[1] with reference to the need of such a society, and early in 1876 his efforts resulted in the formation of the Mineralogical Society of Great Britain and Ireland, of which he became the first honorary general secretary and editor of the magazine,[2] both of which positions he occupied until his departure for Spain in 1881. Many years later, in 1892, in conjunction with the late Geo. Seymour, Prof. Huntingdon, Claudet, Ferguson, Cox, Alford, and others, he took a prominent part in the formation of the Institution of Mining and Metallurgy, of which he became a vice-president, filling the presidential chair in 1895–6. For his services the Institution made him an honorary member, a distinction also conferred upon him by the Imperial Mineralogical Society of St. Petersburg, the Royal Cornwall Polytechnic Society, the Royal Institution of Cornwall, and the Royal Geological Society of Cornwall, of which last he occupied the presidential chair in 1904. The two last-mentioned societies also awarded him respectively the Henwood and the Bolitho gold medals, in each case the greatest honour in their power to bestow.

Mr. Collins's literary activities were great. In addition to the books already referred to, he brought out a translation of Moissenet's 'Lodes of Cornwall', a 'Catalogue of the works of Robert Were Fox, F.R.S.', Museum Catalogues of the minerals in the Royal Institution of Cornwall,

[1] J. H. Collins, 'Formation of a Mineralogical Society.' Letter to Geological Magazine, 1875, p. 569.

[2] An appreciation of his early services to the Society appeared in the minutes (vol. iv, p. xviii; vol. v, p. iv).

and various other separate pamphlets. Five of his papers are to be found in the Quarterly Journal of the Geological Society, twenty (including short notices) in the Mineralogical Magazine, four in the Transactions of the Institution of Mining and Metallurgy, seventeen in the Transactions of the Royal Geological Society of Cornwall, eighteen in the Journal of the Royal Institution of Cornwall, in addition to innumerable articles in the Mining World, Iron and Coal Trades' Review, English Mechanic, Engineering and Mining Journal, Mining Magazine, and other periodicals.

Mr. Collins married in 1863, and had five sons and four daughters. Three of the latter are married, the other died in infancy. Of the sons the eldest, Henry, the fourth, George, and the last, Edgar, survive him, and all have become mining engineers. The second, William, after a brilliant career at Cambridge and as Professor of Ecclesiastical History at King's College, London, was consecrated Bishop of Gibraltar in 1904, and died at sea off Smyrna in March, 1911. The third son, Arthur, who was also a mining engineer, was murdered at Telluride, Colorado, in May, 1902, by emissaries of the Western Federation of Miners, with whom he had come into conflict over the principle of the 'open shop.'

H. F. C.

Henry Bedinger Cornwall (1844–1917) was from 1873 to 1910 Professor of Analytical Chemistry and Mineralogy in Princeton University, New Jersey. He wrote on water analysis, and of his few mineralogical papers there are two on the presence of gallium and indium in American blendes. In 1882 he brought out a 'Manual of blowpipe analysis, qualitative and quantitative, with a complete system of determinative mineralogy', a second edition of which appeared in 1888.

Carl Adolf Ferdinand Hintze (1851–1916) was born at Breslau on August 17, 1851, and died there of heart failure on December 28, 1916. After studying at Breslau, Bonn, and Berlin, he became in 1872 assistant to Professor P. Groth in the new university at Strassburg, where he graduated in 1873. Between the years 1875 and 1886 he carried on the business of a dealer in minerals, first in Strassburg, and later in the employment of the firm of Krantz at Bonn. In 1884 he was a Privat-Dozent for Mineralogy and Crystallo-chemistry in the University of Bonn, and in 1886 was appointed Extraordinary Professor of Mineralogy at Breslau, becoming in 1892 Ordinary Professor and Director of the Mineralogical Institute and Museum, which post he held until his death.

Most of his early work appeared as papers on the crystallography of various minerals and organic compounds, the first, in 1871, being in collaboration with Groth on the crystallography of bloedite. Later he applied himself with energy to the compilation of his monumental work of reference, 'Handbuch der Mineralogie', vol. ii (1,841 pp.) of which, treating of the Silicates and Titanates, appeared during the period 1889–97. Volume i, of which sixteen parts have appeared (1898–1913), already extends to 2,560 pages: in this the Elements, Sulphides, Oxides, and Haloids are completed, but unfortunately there still remain untouched the Carbonates, Sulphates, Borates, and Phosphates.

George Christian Hoffmann (1837–1917), a member of this Society since 1888, was born in London on June 7, 1837. He studied at the Royal School of Mines and the Royal College of Chemistry, where he acted as an assistant to A. W. Hofmann. After working as a research chemist in England, he visited in 1861 Natal, Mauritius, and Australia, settling down in Melbourne. Here he worked in the chemical laboratory of the Botanical Garden under Baron F. Mueller, and published many papers on phytochemistry and reports on economic vegetable products. In 1872, on the retirement of T. Sterry Hunt from the Geological Survey of Canada, he was appointed assistant to B. J. Harrington in the chemical and mineralogical laboratory. Later he became chemist, mineralogist, and assistant-director of the survey, from which he retired in 1907. He took a lively interest in Canadian minerals, describing many new occurrences and publishing the results of a multitude of analyses and assays. Baddeckite and souesite, both from Canada, he described as new species. He died at Ottawa on March 8, 1917.

James Brown Jordan (1838–1915) was born on August 31, 1838, and died at Torquay on December 1, 1915. His father, Thomas Jordan, was in 1840 the first Keeper of Mining Records in the Mining Record Office, then under the Department of Woods, being succeeded by Robert Hunt in 1845. J. B. Jordan was appointed in 1858 an Assistant Keeper in the same office, which at that time was located in the Museum of Practical Geology: later, on its transference to the Home Office in 1883, he became a Clerk of Mineral Statistics, from which post he resigned in 1900. He devised a sunshine recorder, a glycerine barometer, an improved apparatus for preparing micro-sections of rocks, and constructed various geological models. He published in 1862 and 1873 a series of nets for the construction of models of crystals.

John Wesley Judd (1840–1916).—By the death of Professor Judd both mineralogy and geology have lost a distinguished investigator and an able exponent. It is pleasant to remember that he had enjoyed some ten years of well-earned but by no means unproductive leisure since his retirement from official duties.

His broad sympathies and wide scientific attainments were, in part at least, the result of an unusually varied career. After a school training at Portsmouth and in London, he studied for the teaching profession at Westminster, and became for a time master of a school in Lincolnshire. But the work of an elementary teacher did not appeal to him, his inclinations lying in the direction of natural history. He became interested especially in geology and mineralogy, and as a result of examinations held in these subjects by the Science and Art Department attracted the notice of Ramsay and Smyth, through whose advice and assistance he eventually became a student at the Royal School of Mines in Jermyn Street. Here he came under the influence, not only of these two professors, but also of Hofmann, Tyndall, Huxley, and others. On completing his course at the school he accepted a post as analytical chemist in one of the large iron and steel works of Sheffield, and it was during this period that he initiated his life-long friendship with Sorby, from whom he acquired his first insight into the study of rocks and minerals in thin sections—a method of study at that time in its infancy. Subsequently he was appointed temporarily to the Geological Survey in order that he might continue and complete work which he had already begun on the Mesozoic rocks of Lincolnshire and Yorkshire and of certain of the midland counties. At a later date he was attached for a short time to the Board of Education as an inspector, in association with Matthew Arnold.

When once more free to return to his geological studies he devoted himself to the outlying patches of Mesozoic strata in the north-east and the west of Scotland, concerning which he produced a classic series of papers under the familiar title of 'The Secondary Rocks of Scotland'. During his labours in the western area he became interested in its igneous rocks, and by his conclusions with regard to these he attracted the attention and sympathetic interest of Darwin, Lyell, and Scrope. At the suggestion and with the help of the last of these, Judd visited and studied all the principal volcanic areas of Europe, presenting the results of his investigations in his well-known 'Contributions to the Study of Volcanoes'. The wide knowledge of the phenomena of eruptive areas which this experience gained for him enabled him in later years to write with unimpeachable authority the admirable volume on 'Volcanoes: what they are and wha

they teach' (1881), with which his name will always be associated. It is not always remembered that Judd to a large extent evolved and elaborated the generally accepted classification of igneous rocks, which had already been adumbrated by Bunsen. The institution of 'Intermediate' and 'Ultra-Basic' classes, to include rock-types which did not lie naturally in Bunsen's 'Acid' and 'Basic' groups, we owe to him. He was the first to suggest the geographical distribution of consanguineous rock-types which is expressed by his term 'petrographical provinces', and which has proved such a helpful pointer in the latter-day study of the natural history of igneous rocks.

The standing which Judd had acquired among British geologists was demonstrated in 1876 by the offer of the professorship of geology in the Royal School of Mines in succession to Ramsay on the appointment of the latter to the directorship of the Geological Survey. This post he accepted, and held with great distinction and with much benefit to geological science for nearly thirty years. His desire to introduce adequate courses of practical instruction, similar to those created for biological teaching by his colleague Huxley, led to the transfer of the geological department from Jermyn Street to more spacious quarters at South Kensington, and here in 1881 it and associated departments were linked together to form the Royal College of Science. On the death of Huxley in 1895 Judd became Dean of the College, and continued to hold that office until his retirement in 1905.

Besides his contributions to geology, Judd made many to mineralogy, principally during the tenure of his professorship. These included papers on the determination of the felspars, on the orthorhombic pyroxenes, on gliding- and solution-planes and schillerization, on certain peculiarities of quartz and on other forms of silica, on the scapolitization of felspar, and on the natural history of corundum and the ruby. Particulars of these and his other writings are given in the Geological Magazine for September, 1905, and April, 1916.

Judd became a Fellow of the Royal Society in 1877. He acted as a secretary of the Geological Society from 1877 to 1886, and was elected President in the latter year. He was created C.B. in 1895. For many years (1892–1906) he served as Foreign Secretary of the Mineralogical Society.

His was a lovable personality. His many friends will recall with affection his fine presence, his simplicity and punctiliousness in the matters of dress and personal appearance, his quiet sense of humour, and his kindly and courteous manners. Sensitive himself, he was most

considerate of the feelings of others; but having a strong sense of duty he never shrank from conflict or the expression of righteous indignation if, according to his convictions, these were demanded. As an original worker, he was meticulously careful of details, but did not allow these to impair his vision of broad issues and large principles. As a teacher, he endeavoured to present his subject clearly and accurately, while at the same time imparting to it that dignity and inspiration which he firmly believed it to merit. The courses which he built up at the Royal College of Science were models of admirable organization, and have served as the basis upon which numerous others in many parts of the world have been founded. Their outstanding feature was the importance given to practical instruction, and it is to this impression and amplification of theory by practice that the highly productive results of his academic work have been largely due. Whether as a discoverer of new knowledge, or as an exponent of that already gained, his services to the science he loved will live long after him.

C. G. C.

Carl Georg Richard Lepsius (1851–1915), since 1874 Professor of Mineralogy and Geology in the Technical High School at Darmstadt, and Director of the Geological Survey of Hesse. His chief work was geological, but he also wrote on rock metamorphism.

Domenico Lovisato (1842–1916) was born at Isola in Istria, and as a youth in 1866 enrolled with Garibaldi's volunteers. After banishment as a conspirator, he taught mathematics in a school, and in 1878 gave instruction in mineralogy in the University of Sassari in Sardinia. Since 1884, until his death on February 23, 1916, he was Professor of Mineralogy and Geology in the University of Cagliari, Sardinia. In 1880 he accompanied as geologist the Italian expedition to South America; and he gave a description of the rock specimens collected in Tierra del Fuego by the French expedition of 1882–3. His chief work, however, dealt with the geology and mineralogy of Sardinia, on which he published many papers. Rosasite he described as a new species, and barium-heulandite as a new variety. He was elected a member of the French Mineralogical Society in 1887, and in the Bulletin (1916, vol. xxxix, pp. 82–83) of that Society Professor A. Lacroix has given a notice of his life and work.

Ernst Ludwig (1842–1915) was, since 1872, Professor of Applied Medical Chemistry in the University of Vienna, and in 1883 he was

elected an honorary member of this Society. During the period 1870–83 he published the results of many mineral analyses, more particularly of silicates, while during the longer period, 1865–1901, he analysed a number of Austrian mineral waters. The mineral ludwigite was named after him by G. Tschermak in 1874. He was born at Freudenthal in Austrian Silesia, and died on October 14, 1915. An obituary notice, by F. Berwerth, has appeared in Mitt. Wiener Mineralog. Gesell., 1916, No. 77, pp. 2–17 (issued with Min. Petr. Mitt., 1917, vol. xxxiv).

Henry Skeffington Poole (1844–1917) was born in Nova Scotia and educated at King's College, Windsor, where he took the degrees of M.A. and D.Sc. He also studied at the Royal School of Mines, London, gaining the associateship in 1867, and was elected a Fellow of the Geological Society in 1866. In 1872 he was appointed Government Inspector of Mines in Nova Scotia; and subsequently, for about twenty years, he acted as manager of collieries in Nova Scotia. He was the author of several papers and reports on mining geology, more especially with reference to coal and gold, some of which were prepared for the Geological Survey of Canada. His father, Henry Poole, had also written on the Nova Scotian coal- and gold-fields, and this has given rise to some confusion in the Royal Society's Catalogue of Scientific Papers.

Very shortly before his death, on March 31, 1917, at Stoke near Guildford, Surrey, he had decided to present his collection of minerals, ores, and rocks to the British Museum. The value of this collection lies in the number of well-localized specimens illustrating occurrences in eastern Canada, more particularly Nova Scotia, where Dr. Poole had such exceptional opportunities for collecting.

Sir William Ramsay (1852–1916), the celebrated chemist, was a nephew of the Scottish geologist, Sir A. C. Ramsay. He will be remembered by mineralogists as the discoverer, in 1895, of helium in uraninite, fergusonite, and other minerals.

Robert Henry Scott (1833–1916), a past-President and Trustee of this Society, died on June 18, 1916, at the advanced age of eighty-three. He was born of Irish parentage in Dublin on January 28, 1833, and, after a school education at Rugby, had a brilliant career at Trinity College, Dublin, graduating in 1855 in experimental physics. He afterwards (1856–8) studied chemistry, physics, and mineralogy at Berlin and Munich. In 1862 he was appointed Keeper of Minerals and Lecturer

on Mineralogy to the Royal Dublin Society. It was during this period (1862–7) that his original work in mineralogy was done. This dealt more particularly with the minerals and granites of County Donegal; but he also gave an account of the minerals of Strontian in Argyllshire. In collaboration with Prof. S. Haughton he edited in 1862 G. C. Mahon's 'Mineral Agents' Handbook' and A. Smith's 'Blowpipe Vade Mecum', and in the same year published a 'Manual of Volumetric Analysis'.

In 1867 he was appointed Director of the new Meteorological Office in London, a title changed in 1877 to Secretary of the Meteorological Council. This post he held until his retirement in 1900, and it was as 'Clerk of the Weather' that he was best known, and in this subject that he did his best work. He did not, however, entirely give up his interest in minerals, for he was an original member of the Mineralogical Society, serving on its first Council (1876), and energetically acting as General Secretary (1881–8) and Editor of the Journal (see Min. Mag., vol. viii, p. 144). Later he was President (1888-91), and since 1894 a Trustee of our Society. He was elected a Fellow of the Royal Society in 1870, and received the honorary degree of D.Sc. of Dublin in 1898. He was also an Officer of the Legion of Honour.

Silvanus Phillips Thompson (1851–1916), the well-known physicist, wrote papers on the optical and electrical properties of tourmaline, and on the nicol prism and other polarizing devices. He was much interested in the early history of physics, and prepared English translations with notes of Huygens's 'Treatise on Light' (1912) and Gilbert's 'De Magnete' (1900), the former dealing with 'the strange refraction of Iceland crystal', and the latter with loadstones.

Isidor Weinberger (1838–1915), a founder and honorary member of the Vienna Mineralogical Society, and a councillor of commerce, died on August 15, 1915, in his seventy-eighth year. In early life, as an official on the Hungarian railways and stationed at Dognacska, he had opportunities for collecting minerals. Later he was connected with iron mining and smelting in Bohemia. His collection of minerals is very complete for a private collection; some particulars respecting it are given in the 'Mineralogisches Taschenbuch' (1911, p. 186) of the Vienna Mineralogical Society. The frontispiece of the volume just quoted shows his portrait. The meteoric mineral weinbergerite was named after him by F. Berwerth. An obituary notice has appeared in Min. Petr. Mitt., 1915, vol. xxxiii, pp. 521–2.

REVIEWS.

Economic Geology. By Heinrich Ries. Pp. xviii + 856, with 75 plates and 291 text-figures. Fourth edition. (New York: John Wiley and Sons, Inc.; London: Chapman & Hall, Ltd. 1916. Price $4.00 = 17*s.* net.)

The first, second, and third editions of this book appeared under the title 'Economic Geology of the United States' and were published (in 1905, 1907, and 1910 respectively) by the Macmillan Company of New York. The fact that it has already reached a fourth edition alone proves its value; and as a matter of fact it is full of useful and concise information concerning mineral deposits of all kinds. Although in this edition the book has been considerably enlarged, yet it still deals primarily with the mineral resources of the United States. Canadian deposits are now, however, treated at some length, but those of other parts of the world are briefly mentioned in a very scrappy and insufficient manner. Again, the bibliographical references, while very full for the United States and giving just a few for Canadian occurrences, omit entirely those of other parts of the world. We therefore think that the old title of the book is more descriptive of its contents than is the new title. Part I on 'nonmetallics' covers a wide range: coal, petroleum, gas, building stones, clay, limes and cement, salines, fertilizers, abrasives, precious stones, underground waters, &c.; while Part II on ore-deposits treats of the metallic ores.

The illustrations are numerous and excellent, but they are numbered in rather a curious manner. The 'plates' are on the numbered pages with the text printed on the back, and the figures they carry do not differ in character from the consecutively numbered series of text-figures. In all there are 417 figures. The book is very clearly printed and is well bound. For its size, it is extraordinarily heavy, weighing only an ounce short of four pounds. It, in fact, affords an excellent example of a paper heavily loaded with mineral matter; but, although the economic uses of the various minerals are stated, we find in the very full index no reference to the mineral loading of paper; nor does the name 'agalite' appear, although this material is much used in American book-papers.

The Banket. A study of the auriferous conglomerates of the Witwatersrand and the associated rocks. By ROBERT B. YOUNG. Pp. xv + 125, with 28 plates and 1 text-figure. (London: Gurney & Jackson. 1917. Price 8*s.* 6*d.* net.)

This book is based on the several papers dealing with the Rand banket which have been published by the author during the past ten years. The work of other authors is, however, also freely quoted and many references to the literature are given, but the addition of a systematic bibliography would have been useful. A detailed description illustrated by numerous good figures is given of the characters and mode of occurrence of the rock, and of the original and secondary minerals of which it is composed. Amongst the original minerals, the presence of diamond, iridosmine, and platinum is of interest. The diamonds are invariably green in colour. Only one has been actually found in the matrix, but many small stones have been found in the black sands from the battery stamps. The largest on record is one of eight carats. Amongst the secondary minerals, small crystals of anatase rich in faces are recorded.

The origin of the relatively small amount of gold (averaging 6½ dwts. per ton, and rarely visible as small, hackly grains) has been the subject of much controversy. Whilst the author at first favoured the infiltration theory, he now accepts the placer theory. With the latter theory it is necessary to assume that the whole of the original gold has been dissolved and re-deposited in place; but seeing that the rock has undergone profound metasomatic changes (e.g. the replacement of quartz pebbles by pyrites) this is quite admissible. The history of the rock is traced out somewhat as follows. The conglomerate was of marine origin and composed largely of pebbles of vein-quartz, together with some heavy minerals (iron-ores, gold, &c.), derived from the metamorphic rocks of the Swaziland System. It was cemented by quartz, folded, faulted, and intruded by igneous masses. The complex mineral changes which it has undergone include: (1) Solution and re-precipitation of the gold. (2) Conversion of the iron-ores (magnetite and ilmenite) into pyrites and rutile by the action of sulphuretted waters. (3) Subsequent solution and re-precipitation of a portion of this secondary pyrites. (4) Formation of chloritoid, sericite, and chlorite at the expense of argillaceous and felspathic material. (5) Introduction of some metallic sulphides, chlorite, sericite, calcite, and carbonaceous matter (small nodular grains of 'carbon') derived from the later igneous intrusions.

A Study of the Magmatic Sulfid Ores. By C. F. Tolman and Austin F. Rogers. Pp. 76, with 20 plates and 7 text-figures. (Leland Stanford Junior University Publications, University Series. 1916. Price $1.00.)

In this essay two general classes of magmatic sulphide ores are considered, namely: (*a*) nickel- and copper-bearing pyrrhotite deposits (e. g. those of Sudbury in Canada, and of Norway), and (*b*) chalcopyrite-bornite deposits (e. g. those of Ookiep in Namaqualand, and of Plumas Co., California). Both of these types are associated with dykes and sills of basic igneous rocks, such as norite, gabbro, and peridotite. A general discussion of the origin of these ores is followed by the results of microscopical examination of thin sections and of polished opaque sections of specimens from several typical localities. The sulphides have been introduced by the aid of mineralizers at a late stage in the sequence of magmatic events, being later than the silicates, which they partly replace.

The Magic of Jewels and Charms. By George Frederick Kunz. Pp. xv + 422, with 56 plates and 29 text-figures. (Philadelphia and London: J. B. Lippincott Co. 1915. Price $6.00 net.)

This is a companion volume to Dr. Kunz's 'Curious Lore of Precious Stones' (1913; reviewed in this Magazine, vol. xvii, p. 125), and is got up and illustrated in the same elegant style The fact that he has been able to follow so soon with a second volume (which, however, does not treat of gems alone) on much the same lines as the first, speaks much for his stores of miscellaneous information. The following selection of the chapter headings will indicate the scope of the book, which is full of quaint and interesting reading: magic stones and electric gems; meteorites or celestial stones (pp. 72–117); stones of healing; virtues of fabulous stones, concretions, and fossils; snake-stones and bezoars; religious use of various stones; amulets; facts and fancies about precious stones.

The Prodromus of Nicolaus Steno's Dissertation concerning a solid body enclosed by process of Nature within a solid. An English version with an introduction and explanatory notes by John Garrett Winter, with a foreword by William H. Hobbs. University of Michigan Studies, Humanistic series, vol. xi, part II, 165–283, with 7 plates. 1916. (New York: The Macmillan Company. Price $1.30 net.)

Steno's Prodromus, or preliminary to a larger treatise (which was never

completed), first appeared in Latin at Florence in 1669. There have been several reprints, and an English translation was published in 1671. A new English edition of this historical work is therefore welcome. The translator has evidently taken a great interest in the work, and has added much to its value by the numerous critical and explanatory notes. The usefulness of the volume is also increased by the addition of an excellent biography of the author, a complete bibliography, and a full index. The illustrations include two portraits of the author, and reproductions of the original title-page, first page of the original text, and of Steno's figures. The thirteen figures of vertical and horizontal sections of 'the angular bodies of crystal' [i. e. crystals of quartz] illustrate clearly Steno's important law of the constancy of the interfacial angles of crystals and his views as to the growth of crystals.

Os Satellites do Diamante. By Eugenio Hussak. Pp. 56, with 3 maps (Rio de Janeiro: Serviço Geologico e Mineralogico do Brazil. 1917.)

The manuscript notes on the minerals associated with the diamond in Brazil, which were left by Dr. E. Hussak at the time of his death in 1911 (Min. Mag., vol. xvi, p. 247), have been translated and edited by his colleague, Jorge B. de Araujo Ferraz of the Brazilian Survey. Particulars are given respecting 56 mineral species, many of which were discovered by Hussak, and some described by him as new species. A summary of results and a bibliography are appended. It would have been fitting to include in this volume a good biographical notice of the author.

Bibliography of Yorkshire Geology. By T. Sheppard. Pp. xxxvi + 629. (London, Hull, and York: A. Brown & Sons, Ltd. 1915. Price 15*s*.)

This is issued as vol. xviii of the Proceedings of the Yorkshire Geological Society, and forms the C. Fox-Strangways' Memorial volume. It is based on an uncompleted manuscript covering the years 1534–1892, left by the late C. Fox-Strangways; this has been added to and brought up to the year 1914. The titles of books, papers, and notes, with the references, are arranged chronologically under date of publication, and under each year alphabetically according to authors. There are, for example, 124 entries for the year 1913, and 169 for 1914. At the end of the volume is a long index of authors and subjects. A list (20 pp.) is given of the scientific periodicals that have been indexed, and there is also a complete list of the Geological Survey maps and sections relating to the county. The work appears to have been done very thoroughly; but some of the entries are quite trivial, for which, however, the compiler offers an apology.

Bibliography of Australian Mineralogy. By C. Anderson. Pp. 164. Mineral Resources, No. 22, Geological Survey, New South Wales. (Sydney, 1916. Price 2*s.* 6*d.*)

The titles of about one thousand papers are listed under the names of authors and numbered consecutively. Whilst a large part of them occur in Australian scientific journals and mining reports, still there are not a few to be found in foreign journals. Only original matter of scientific value has been included, and the author has laboriously referred to all the original sources whenever possible. For each of the seven States of the Commonwealth there is given a separate subject index of mineral names and a locality index, reference being made to the numbered entries in the list of titles. This plan is no doubt the more convenient for local use, but for the general worker it would have been more convenient to have one subject index rather than seven (or indeed eight, there being an extra one for Australia generally). The work has occupied the author during his spare time for the last ten years, and he has been at especial pains to localize carefully each occurrence.

Microscopic Determination of Opaque Minerals, an aid to the study of ores. By Joseph Murdoch. Pp. vii + 105, with 1 coloured plate and 9 text-figures. (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd. 1916. Price 9*s.* 6*d.*)

The metallographic method of examining polished and treated sections by reflected light under the microscope appears to have been first seriously considered for opaque minerals by the American metallurgist William Campbell in 1906. Since then a considerable amount of work in this direction has been done in connexion with the ore-deposits of the United States; and the subject, for which the name 'mineralography' is proposed, is likely to grow in importance. So far, however, there has been no systematic determination of the characters and reactions under these conditions of the several mineral species. This task the author set himself in 1911, and he has examined every available species or supposed species (many of which prove to be mixtures) in American collections amongst the sulphide and sulpho-salt groups, including selenides, tellurides, and arsenides. The book gives an interesting historical review, a bibliography, and an account of the technique of the method. But, unfortunately, instead of recording his observations in a systematic manner, the author has thrown them into the form of determinative tables. The system of tabs to the right and tabs to the left and of pages partly cut away is certainly ingenious, but irritating

to anybody wishing to learn something of the method and not actually having in hand a specimen for identification. Again, there is a very unnecessary system of abbreviations, in spite of the fact that several pages are almost blank and many lines of only part length. Although the book will be of considerable, if only passing, value, it seems a pity that the author should have missed an opportunity of producing one which would remain a standard textbook on the subject. The few text-figures illustrating the apparatus needed for the method are good, and the one plate of sections is excellent; but several more pictures of sections would have been an advantage.

A Pocket Handbook of Minerals designed for use in the field or class-room, with little reference to chemical tests. By G. MONTAGUE BUTLER. Pp. ix + 311, with 89 text-figures and 5 tables. Second edition. (New York: John Wiley & Sons; London: Chapman & Hall, Ltd. Not dated. Price 11*s.* 6*d.*)

The first edition of this handy little pocket-book was published in 1908, and the present edition presumably appeared in 1911 (to judge from the statement that the book was copyrighted by the author in 1908 and 1911). It gives a synopsis of the prominent and essential characters of the more important mineral species, such as will be useful to students and amateurs. Space is left on each page for the addition of notes. In this edition, with an increase in size of thirteen pages, specific gravity values are quoted, and a few additional species are included. An appendix of miscellaneous information includes a glossary, prices of metals, minerals, and cut gems, &c. The book is clearly printed on thin paper and is elegantly bound in leather with gilt edges, but the price is rather prohibitive.